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COMPOSTING OF ORGANIC WASTES - AN ANNOTATED BIBLIOGRAPHY

John S. Wiley

Public Health Service
Savannah, Georgia

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AN ANNOTATED BIBLIOGRAPHY

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Savannah, Georgia

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COMPOSTING OF ORGANIC WASTES--AN ANNOTATED BIBLIOGRAPHY

John S. Wiley, Editor
Equipment Development Section

Introduction

A survey of the literature on the composting of organic wastes was made concurrent with research work by the Communicable Disease Center, Technical Development Laboratories. This bibliography, with abstracts and occasional editorial remarks, may serve as a source of information for those interested in the subject. Two excellent bibliographies (30) and (86) exist. Yet recent increased interest in composting for community solid waste treatment in the U. S. has greatly increased the literature since 1950.

The subject matter is limited to composting which may be defined as a process in which microorganisms break down organic matter to a relatively stable humus-like material. It is distinguished from digestion or fermentation in that the decomposing material is primarily discrete solids with open pore spaces rather than solids in a liquid or semi-liquid environment. Composting processes vary from anaerobic to aerobic and from mesophilic to thermophilic decomposition. However, aerobic thermophilic composting is generally believed to provide the most rapid and complete decomposition of the readily oxidizable or putrescible matter. Most of the references deal with actual or attempted aerobic thermophilic decomposition. They also deal largely with the composting of municipal refuse or garbage, sometimes with additional materials such as sewage sludge, night soil, or manure. Composting as a means of municipal waste treatment should, from a public health standpoint, be a sanitary and nuisance-free process which results in material which will not breed vermin, contain pathogens, or be a health or nuisance hazard. The process must be competitive economically with other accepted methods of waste treatment or disposal. Municipal refuse composting may result in salvage or by-product accumulation with some economic or agricultural value. Of the compost itself, neither type of value has been scientifically or practically (as by supply and demand) determined yet in this country. This lack, however, should not deter development of the process for community waste treatment if, upon careful technical analyses, the process is demonstrated to be competitive with other accepted methods of waste disposal.

In the United States, Waksman's work has become classical in the field of aerobic decomposition. The first basic studies on refuse composting were conducted during 1949 to 1953 by the University of California. These studies concluded, with regard to windrow composting, that "The time required for composting varied from about 12 days, for a C/N ratio of 20, to about 21 days for a C/N ratio of 78" (31). Studies at Michigan State University and the CDC Technical Development Laboratories indicate that de-watered garbage or refuse can be composted through one cycle of decomposition in mechanical units in an appreciably shorter time, perhaps a week or less. A few cities, notably San Diego and Tacoma, have studied composting in pilot plants. Full scale compost installations in the U. S. have largely resulted in failures or discontinuance, many because of inadequate preliminary research and testing. Of some 15 plants, five or less remain in operation at this writing and none has adequately demonstrated economical municipal refuse or garbage composting.

Much basic information is now available on decomposition by composting and present problems are primarily economic plant operation and materials handling. Some of the full-scale plants installed have helped materially in this respect in spite of subsequent discontinuance.

The pilot plant at Chandler, Arizona, operated by the CDC Phoenix Field Station is now supplying "know-how" and cost data on the preliminary materials handling of refuse and on outdoor composting. Engineers and municipal officials should know reasonably soon if that type of composting is an approved, competitive method for the treatment of community solid wastes in that area.

The composting studies conducted at the CDC Technical Development Laboratories should lead to design and operational improvements in high-rate mechanical composters for treating community solid wastes in the United States.

Bibliography on Composting of Organic Wastes

The following references, with abstracts and editorial comments, are listed alphabetically by name of principal author and are numbered consecutively. At the end is a brief index of subjects. References are largely reports and journal or magazine articles. No patents are included and only a few books and monographs, which could not be comprehensively abstracted here. Attempt has been made to reduce the number of anonymous references by placing them under organization, city, or composting process names. Quoted portions or entire abstracts are the author's unless indicated as from an abstracting journal; unquoted abstracts are by the editor. Editorial comment is made parenthetically and is so noted.

1. Amer. Soc. of Civil Engineers (Committee on Refuse Collection and Disposal). Composting and grinding. ASCE Proceedings, Separate No. 556, 22 pp and references Nov. 1954

Composting (pp 4-11):- Anaerobic composting failed in U.S. and composting here will depend on aerobic decomposition. Fundamental steps are (a) removal of non-compostables, (b) grinding, (c) moving and placing for composting, (d) turning or aerating, (e) regrinding and bagging or storing in bulk. (Ed. note: drying is left out.) Practically, it is assumed that mixed refuse will be delivered at the plant. Thus, a conveyor belt with magnetic sorter for Fe metals must be provided. Glass and other non-combustibles will be removed by hand picking. Hand picking of rags and paper may be profitable. (Blower arrangement may work for removing paper). About 66% of refuse can be composted. Initial C/N ratio should be 30-35, above 50 the process is slow and results in lower quality of finished compost.

Development of suitable grinders must be solved. Grinding is necessary to render refuse fit for composting. It must not become too soggy. Moisture should be 40-65%. One can add straw, paper, soil or sawdust if moisture is too high.

Adding organisms does not appear necessary. Various cells or digesters, with provision for aeration, have been developed. Open air composting, to keep costs down, can be practiced in areas of U. S. where rainfall is low and ground temperatures high. Sheds may be used where rainfall is high. Turning, as recommended by the University of California project, is discussed. Composting with raw or digested sewage sludge will increase N. The amount of sludge added depends on moisture.

1. Finished compost is judged by temperature, odor, color, and physical appearance and should have a C/N ratio of 20 or less. Open air composting takes 12 to 21 days. Special turning equipment is needed and care exercised to turn in the outer layers. Re-grinding and drying of finished compost may be needed. (The various U. S. plants are discussed.) Composting is not yet on a commercial basis in U. S. A comparative cost with other methods of disposal will determine whether composting can compete or not. Composting may be more acceptable than hog feeding, dumps, and landfilling because of better fly, odor, and air pollution control. Composting may be shown to be economical in many cases.

Grinding (pp 12-23):- This section discusses household grinders, central stations, and reviews the various installations. Where garbage is treated in sludge digesters the loadings (lbs. dry solids per cu. ft. per month) doubled, resulting in need for increased digester capacity (Findlay, Ohio). Five cu. ft./capita of digester has been recommended.

2. Amer. Soc. of Civil Engrs. (Committee report). Pilot plant composting of municipal garbage at San Diego, California. *Proc. ASCE* Paper 887 J. San. Eng'g. Div., 82 (SA 1), 7 pp Feb. 1956 Wiley, John S. Discussion *ASCE Proc.* Paper 1048 (J. San. Eng'g. Div., 82 (SA4)), pp 17-20 Aug. 1956

This report greatly condenses the material presented in a report by the Sewage Treatment Division, City of San Diego (89) describing pile and windrow composting of garbage by that City. The pilot plant included a garbage transfer ramp, grinder, skip loader, and other operating equipment. Characteristics of the raw garbage and finished compost were:-

	% H_2O	% N	% P_2O_5	% C	C/N
Raw garbage	68-74	2.3-2.8	1.2-1.7	46.6-51.8	18.1-22.0
Final compost	10-25	1.0-2.1	1.2-2.3	12.8-31.9	11.2-21.6

Twelve experimental compost piles and one small windrow were established, turned and wetted at intervals, then analyzed. Some additives to the garbage tried were: digested sewage sludge, kelp, straw, and paper. Composting was conducted a maximum of 90 days. "The pilot plant operating costs ranged from $1.56 for composting 1 ton unground garbage through $20.48 for grinding garbage and supplying a straw additive." A cost per ton table is given for the twelve piles and costs were discussed in comparison to other methods of disposal of refuse.

2. Conclusions are: 1) The garbage required several days of drainage so that aerobic composting could take place. Some early fly breeding occurred and insecticide was used; 2) Complete stabilization required 30 to 90 days of composting. Precutting and mixing additives with fresh garbage did not greatly reduce the time; 3) The use of additives did not greatly effect the final nitrogen and phosphate content; 4) About 1/3 of the initial weight of the fresh garbage was recovered in the finished compost; 5) "Costs of $1.56-$20.48 per ton of fresh garbage were incurred for composting." These high costs may limit the application of composting; 6) An estimated 25 acres would be required for a 50 ton/day composting plant.

Mr. Wiley, in discussing the paper, pointed out the difficulty of attempting to compost plain wet garbage. It has poor structure and too great a moisture (and other liquid) content to compost well aerobically. Additives to reduce moisture were not added in sufficient amount to reduce moisture in any test below 59.5%. Composting refuse, instead of garbage, is more satisfactory because of better structure, pore space, and moisture content and faster composting. By applying the analyses to initial and final weights, the discussor computed the weights and losses in various constituents during composting. He found that they were incompatible because in moving piles the dry matter increased markedly while the volatile matter was greatly decreased. A suggested explanation is that a good deal of sand or soil was picked up in each of the compost piles because of the large number of turnings made on the ground.

Cost computations in the San Diego report were on the basis of cost per ton of final pile weight while the ASCE paper reported them as on the basis of fresh garbage. Values given in the paper should be reduced by 2/3 or to values of $0.63 to $6.93/ton of fresh garbage. The discussor also pointed out that the use of wheelbarrow and shovel to transfer from grinder to pile and forming the pile resulted in excessive costs. Ideally, the materials to be composted should include: combustible refuse, garbage, concentrated or filtered raw sewage sludge, and possibly certain solid industrial wastes.

3. Amrami, A. Agricultural Utilization of Sewage and Public Health Problems. Tavruah (Assn. for Prom. of San. in Israel) 1 (2 and 3) 26-40 Apr. 1957 . (The English edition is semi-annual.)

Regarding sewage sludge as organic fertilizer, there is more safety in digested and dried sludges than in wet sludge (fresh). "There is no objection to adding liquid sludge to

3. garbage compost in windrows if the composting practices conform to the regulations of the Ministry of Health and prevent fly breeding. The high temperature in the compost windrow and the time required for the completion of the process, works towards the destruction of the pathogenic bacteria in the refuse and in the sewage sediments. If the composting is not properly done, then flies breed and the addition of sludge is dangerous inasmuch as the flies coming in contact with it become contaminated with pathogens and transfer them mechanically to the neighbouring areas.... It must be mentioned that the composting practices currently in use in Israel make local compost piles suitable breeding grounds for flies so that the addition of sewage sediments to such piles is not to be permitted. To be sure, wherever the composting system will be in accordance with sanitation demands so that the fly larvae will be destroyed during the composting, such a prohibition may be removed."

4. Anderson, M. S. Garbage composts and related disposal methods. Proc. Local Gov't. Conf. on Refuse Disposal Methods. Univ. of Pittsburgh, pp 83-97 (Apr. 22-23, 1954).

If garbage could be economically returned to land, it might be a sizeable factor in soil conservation of limited areas. The USDA is interested in the possible salvage of some garbage through composting but believes that such organic ammoniates will not be highly competitive in the field of fertilizer nitrogen. Garbage contains small amounts of other essential plant nutrients that are badly needed in certain soils. Raw garbage generally has 1.2 to 2.7% N, 1.6 to 2.5% P_2O_5 and 0.6% K_2O. Composted garbage has 2.0 to 3.0% N, 1 to 3% P_2O_5 and about 1% K_2O. Composting decomposes carbohydrates, fats, proteins, and to some extent lignin, building living organism tissues containing a higher N content than in the mixture. Several groups of organisms prevail and change rapidly during composting. The thermophiles create temperatures of 150-160° F. causing partial sterilization and destruction of weed seeds. Composting increases the mineral content of garbage and changes its character so that it is no longer offensive when wet. Very little data are available on the chemical constituents of garbage composts and many questions need answering through research. Compost may be assumed to contain about 40% stabilized humus, 25% partly decomposed plant material, 10% bacterial bodies, 10% fungus and other bodies, and 15% earthy material. The original garbage probably contained 93% undecomposed plant and animal matter, 7% earthy material, and no humus. Garbage compost N,P,K values would be slightly higher than farm manure but probably would not sell to the farmer as he

4. depends on chemical fertilizers plus "free" animal or green manures. The "town gardener", however, frequently buys such organics as peat, animal manures, and might buy garbage compost. Compost can be used as a mulch after only partial decomposition. It conditions heavy-textured or sandy soils and this effect is prolonged because of slow decomposition. Compost might be suitable for lawn and golf course use, for greenhouse potting mix, and specialty use. Composting refuse (containing combustible rubbish), as against garbage, lowers the quality of the final product but primary consideration is the economics of the entire refuse collection and disposal practices. "Research is needed to determine the rates at which composts of varying composition decompose and thus furnish nutrients to growing plants."

Discussion, p 100. Mr. Shapiro asked Dr. Anderson about the magnitude of the problem of the amount of organic matter in the cultivated soils of the U. S. Dr. Anderson said the best work had been done at the Ohio Agricultural Experiment Station on barnyard manure. It is only worth about 10 [illegible] (sic). However, University of Illinois indicates a little more value for the manure. Anderson said he would pay more for N,P,K in the form of organic material than chemical fertilizer, but he "would not be willing to pay an excessive amount." It should be realized that a "farmer doesn't consider that he has put on an application of manure unless he puts on at least 6 tons of material (per acre, Ed.) that will run 50% moisture." Most experiments in the U. S. are made with 8-12 tons/acre, about once in 3 years; and only on the better lands is it possible to use barnyard manure alone. Dr. Schneider asked what the soil conditioners such as "Krilium" and "Loamium" do for the soil. Dr. Anderson said there are two types: polyacrilon nitril and copolymer, claiming nothing but improving physical defects in problem soils such as clay that is hard for the roots to penetrate. There is no decomposition to give off CO_2 which is produced by organic and may have additional value in plant growth.

5. Anderson, M. S. Compost as a means of garbage disposal. Proc. Florida Soil and Crop Science Society (Paper presented at Clearwater) Mimeo. 18 pp Nov. 29, 1956

Garbage contains carbohydrates, proteins, fats, minerals, and fibers; the water content is usually 70 to 80%. It contains material of possible value to agriculture. Composting systems are of two types: those employing enclosures, and those using ricks, windrows or open heaps. Decomposition may be anaerobic, which is slow and malodorous, or aerobic.

5. With a moisture content of 50 to 60%, temperatures reach 150 to 160° F. in about 3 days with adequate aeration. Composting decreases the carbohydrate content of garbage and accomplishes varying degrees of decomposition of other organic constituents, with the evolution of CO_2 and some loss of N. Some N is transformed into the cells of bacteria or fungi which contain from 5 to 10% N. After a period of several days or a few weeks of composting objectionable odors disappear and the product is of humus-like nature and is said to be stabilized.

Raw garbage contains about 2% N, 2% P_2O_5, and 1% K_2O on a dry basis plus quite a number of other elements. Composts from garbage (Ed. note: some are from refuse rather than garbage) contain varying amounts of constituents ranging, on the basis of 13 samples analyzed by the author: 0.4 to 4.1% N; 0.4 to 3.0% P_2O_5; 0.2 to 2.5% K_2O; 13.0 to 80.6% ash; 6.3 to 8.1 pH range. Concerning the wide range in ash, 8 of 13 samples exceeded 65% and 2 samples were as low as 13%. High ash was probably due to added soil or other mineral matter, making the material difficult to market because of low organic fraction. Nitrification rates, run on those samples containing more than 0.75% N, all were relatively low. The extent of value of various organics, aside from their N,P,K values, is not known. Market and home gardeners have a different viewpoint than the farmer and it is to the former that composts may find a market. "Garbage composts may be useful in several ways: (1) in making potting soils, (2) as mulches, (3) for working into soils of various textures, and (4) for improving soils at the time of establishing lawns. When adequate local supplies are available, market gardeners may use these products instead of animal manures and other organics."

6. Anon. Miami, Fla., adopts the Verdier process of biothermic refuse disposal. The American City 64, 85 Dec. 1949 .

Process, developed by French Engineer J. C. Verdier, is development of the Beccari process. Consists of aerobic digestion of refuse (mixed), including papers, bottles and ash, but not metals. Accomplished in cells designed so that heated or cooled air can be circulated - requires 21 days, under favorable conditions only 11 days. Seeded with liquor from other cells (amount of liquor produced is small). Refuse pulverized in hammermill to pass No. 4 screen. Equipment: crane, hammermill, conveyors, blowers, grinder or pulverizer.

Williams visited the plant in Cannes, France and was favorably impressed in spite of plant damage by a bomb hit. As a result, Miami holds a contract with the Florida Caribbean Biothermal Process Co. and will pay $390,000/yr. to deliver

6. the City refuse to the plant for processing. After 15 years the city will own the plant. The Company will build and operate the plant.

Fine grinding of refuse is still a problem. Los Angeles tried grinding mixed refuse but the grinder exploded when a can of paint thinner went through it.

It is not certain that Verdier process will work with American refuse. Also the market for humus is uncertain. The Verdier process is controlled in U. S. by the Amity Barter and Trade Corp., 29 W. 15th St., NYC. Maurice H. Connell and Assoc., Miami, are consulting engineers for developing the mechanical procedures for its use. (Ed. note: This plant was not constructed, see Williams and Morrison).

7. Anon. Miami, Fla., Grinds rubbish for compost. The American City 65, 21 Jan. 1950

Miami recently acquired a Gruendler grinder, a shredder, a loading table and a set of conveyors for grinding all rubbish. According to R. A. Williams, Dir. of Public Service, this material will be ground into compost for use by the Park Division or for sale to the public and will produce approximately 75-100 tons/day. Rubbish consists chiefly of palm fronds, tree cuttings, shrubbery, and grass cuttings which were formerly dumped into pits. A need is anticipated for compost in nearby citrus and agricultural areas which may develop into a considerable source of revenue for the city. (Ed. note: See Morrison.)

8. Anon. Composting for profit. Eng'g News-Record 148 (26) 44-5 June 26, 1952

The Compost Corporation of America plant at Oakland, California is described. Studies have been conducted for two years and the Company is now ready to undertake large-scale expansion. CCA uses 70 tons of mixed garbage (refuse) per day and makes available valuable humus for farm and garden. The Company thinks that the extra expense in preparing garbage for composting, operating the composting, and marketing the completed product will result in an adequate return on their investment. Richard P. Stovroff, a waste-paper salvage executive, heads the Company and E. E. Pfeiffer is the firm's consultant who has developed bacteria strains which he claims will speed up the composting process. CCA produces 50 tons of compost per day which is marketed as "Com-Co" organic fertilizer by the Ferry-Morse Seed Co. It sells for $34/ton to farmers, $4/100 lb. to gardeners.

8. Steps in the composting process are: 1) removal of salvageable and non-compostable materials using sorting belt, magnet, and blower (for paper removal); 2) addition of soil (5-10%), manure (10-25%), and Pfeiffer's bacterial spray; 3) grinding to average 1 inch size; 4) windrow composting for 3 weeks with one turning; 5) screening, dehydrating in a kiln, pelletizing, and packaging. (Ed. note: as of Jan. 1958 the proposed enlarged plant has not been constructed.)

9. Anon (news item). Expand California City's Composting Operation. Eng'g News-Record 149 (16) 37 October 16, 1952.

Operation of Compost Corp. of America Oakland plant has been suspended pending an expansion program, according to Company officials. After 2 years of development, a standardized design is being developed by Cons. Engr. Office of J. Fruchtbaum of Buffalo, N. Y. Company officials say the new work will cost $180,000 and will be completed next Spring to handle 225 tons/day of garbage, making 100 tons/day of salable compost. (Ed. note: The Oakland plant has not been built as of January, 1958.)

10. Anon. Composting for Profit-II. Garbage to compost: 7 days. Eng'g News-Record 149 (19) 40-41 Nov. 6, 1952

The Frazer-Eweson composting plant at Bay Shore (Long Island), New York is described. Eric Eweson, a bacteriologist, developed the process and J. W. Frazer of Kaiser-Frazer, Frazer Products, Inc., supplied the backing and promoting. Garbage is sorted, ground and conveyed to the top of a 5,000 cu. ft. digester (14 ft. x 14 ft. x 40 ft. high), a wood structure. Some manure goes in with it. The digester is divided by three sets of steel grates into 4 zones or cells. Air is passed through it upwards. The material is dropped from cell to cell by pulling a steel bar back and forth over the top of the grate. Total time is seven days and temperatures of 170-175° F. are claimed in zone 2 (2nd to 4th day). It is claimed that the air which becomes rich in CO_2 as it proceeds upward helps to render the organic wastes assimilable to microorganisms in the decomposing mass. Exhaust vents in the sides at each zone level are provided to control air passage. From the digester, the compost is conveyed on vibrating screens over gas burners for grading and drying. The 10% tailings are returned in seed. Moisture is reduced to 30% and the product is stockpiled for bagging. The plant is designed for 10 tons/day and the compost sells for $68/ton. The plant reportedly cost $100,000. Other Frazer-Eweson plants are located at Mt. Wolf, Pa. and Union Stockyards, Chicago. (Ed. Note: see also 11).

11. Anon (news item). Composting trouble - Maryland city wants out after learning Long Island process doesn't work well. Eng'g. News-Record 150 (17) 24 Apr. 23, 1953

> The Frazer-Eweson composter at Bay Shore, N. Y. is a 10-ton/day plant as designed but is handling only 3 to 3½ tons/week. City officials of Hagerstown, Md. had signed a contract for a similar plant but, when Kurt Wandel (Wandel Machine Co., Downington, Pa.) mentioned the trouble at Bay Shore, decided to try to get out of their contract. Eric Eweson, inventor of the Frazer-Eweson process, admitted failure of the operation. Peter J. Parise and son Leonard, who own 50% of stock at Bay Shore, said the plant had never operated properly - the trouble being in dropping the garbage down from zone to zone through the composter. Hagerstown City Engineer Claude D. Williams said the Maryland Agriculture Department has ordered Hagerstown to stop feeding uncooked garbage to hogs by July 1. He said Hagerstown might turn to the Wandel destructor which grinds garbage with water for subsequent piling or composting on the ground. Wandel Co. has a similar installation at Altoona, Pa. (Ed. note: see also 135.)

12. Anon (news item). Where composting stands - West Coast consultant analyzes age-old waste handling process as method of both recovery and disposal. Eng'g. News-Record 150 (22) 35 May 28, 1953

> Richard P. Kennedy of the San Francisco firm of Clyde C. Kennedy discussed this subject at the 5th Annual Pacific Northwest Industrial Waste Conference in Pullman, Wash. He stated we have made less progress in solving the mechanical problems of composting than we have in understanding the biochemical process. "Successful composting is simply a problem of material handling." While there may be some benefits from special and secret cultures, such inoculum is readily available in the soil, in drainage from compost piles, and even simply from the waste material itself. Although composting is not profitable, the net cost of composting may be less than alternate methods of disposal. Thus, composting may reduce the cost of waste disposal. Factors involved in composting are: aeration, time, moisture, particle size, temperature, and chemical composition. The time required depends a lot on the carbon-nitrogen ratio. Lime and inorganic fertilizers may speed up composting. Pile or windrow composting is described briefly. He reported that the Oakland operation is "practically abandoned." Kennedy's firm has been working since 1948 with pilot plant investigations into possibilities of nitrogen fixation.

13. Anon. They're whittling down the world's largest manure pile. Org. Gard. and Farm. pp 40-42 Dec. 1954

The Chicago Stockyards Compost Company (Darrel Doolen, Gen. Mg.) is composting about one-third of the 50,000 tons of manure collected at the Yards annually. The Company, working with the Chicago Stockyards Research Company, has developed and built three composter machines. A drawing and a picture indicate that the composters are bins with material being fed through the top and discharged through seven horizontal augers at the bottom. Material is re-circulated by bucket conveyor every 1½ to 2 hours being "disintegrated (fan)" and aerated as it is discharged into the bin. Forced warm air, some of which is moistened, is recirculated through the unit with make-up air being supplied as CO_2-laden air is vented. The process is aerobic and reaches thermophilic temperatures, the specified temperature being 145° F. The final product weighs one-third that of the fresh manure and is sold as "Fertilife." The manure is also windrow composted with the use of a machine which "automatically turns the heaps of manure going through the preliminary composting period." This indicates that the manure is first windrowed and then treated in the mechanized cells. Plans are being made to handle all of the Stockyards manure eventually. It is claimed that the method can be used with garbage. Compost is also sold under the name "Gardenure".

14. Anon. Disposal Proposal. The Technology Review (M.I.T.) p 332 May 1955 .

Of all community wastes, garbage is the most difficult problem. It can be burned but incinerators and their operation are costly and apt to pollute the air. Sanitary landfill has weakness at the working surface where fires, stenches, and insect and rodent nuisances inevitably occur. Europe, Asia, and S. Africa have demonstrated that domestic garbage can be composted successfully on a large scale. The garbage is ground and stacked in windrows and aerated by turning with forks about twice a week. The sour odor of garbage disappears as soon as it is ground and aerobic composting produces no foul odors. The materials change from gray-green color to dark brownish-gray. Temperatures reach 75° C. in a few days, then gradually fall to 55° C. after 2-3 weeks. When C/N reaches 20, composting is complete and the compost may be used on agricultural soils without robbing N. The compost provides N,P,K and trace elements for plant growth. It also improves soil texture, increases water retention, and fosters development of extensive root systems. High temperatures in composting kills all common disease germs and parasites. Whether composting will find wide adoption in the

14. U. S. depends upon local climates and financial considerations such as cost of segregating trash, and the economics of storage, distribution, and use as fertilizer of the compost.

15. Anon. Leaf removal pays its way in Toronto. *Pub. Wks*. 86
(11) 84-5 Nov. 1955

Composted and screened leaf mold sells at $1.00/bag [80 lb]. Leaves, collected in Fall, are stored at 6 points during Winter, moved to compost plant in Spring. Leaves are piled in racks 50' x 100' x 10' high, each contains 600 T, portable fences about 4' high hold the sides. No additive or pre-shredding, but seed new leaves with screenings of finished compost. Moisture control and turning. Total time 2 years. Turning is every 6-8 weeks; 16 racks required. Some bottles, cans, etc. in the leaves. Use front end bucket loader into portable Royer shredder; 12 cu. ft. bucket full is cleaned, shredded and discharged in about 15 seconds. Ground material is then hauled indoors by larger tractor buckets. Shredded through larger Royer shredder, loading with tractor bucket and discharged to an oscillating Niagara Screen (small mesh). A brick toting conveyor is rigged for bagging.

Fertilizer value is 2-2-2 with pH of 7. Oak leaves are composted separately for 3 years and sold as an acid leaf mold. Use a 4-ply bag with polyethylene interior.

16. Anon. Typed, 1 p. INTAPUC and compost. (News release) Jan. 1, 1956

Research on composting on an international scale was the subject of a conference last July of over 100 representatives of various interested organizations. It was agreed to form a committee known as the "International Compost Working Party", members coming from countries throughout the world, each being a specialist charged with coordinating the research in one aspect of the subject. Approaches were also made to INTAPUC, the International Association of Public Cleansing to consider how the two organizations might cooperate. Representatives of the two groups met in September at Neuss-am-Rhein with Herr Arns, deputy town clerk, acting as chairman. The two organizations agreed to work closely together. INTAPUC is to be represented by Mr. N. G. Wilson, Manager, Lighting and Cleansing Department of Edinburgh, who is its president. Chairman of the International Compost Working Party is Professor Dr. O. Jaag, Swiss Federal Institute of Technology, Zurich. (Ed. note: In a recent letter from Dr. Jaag an organization known as the International Research Group on Refuse Disposal was described.

17. Anon (news item). Modern factory converts refuse to fertilizer. *Wastes Engineering* 27 (11) 604 Nov. 1956

> "The Orcoa plant at McKeesport, Pa., transforms city's raw garbage, wastes and trash into fertilizer. Erected and operated by the Organic Corporation of America, Pittsburgh, the plant is reported to pulverize all materials in special grinders without previous separation, to speed decomposition by injection of special enzymes and to produce fertilizer in 21 days without odor, smoke or residue." (Ed. note: the plant was permanently closed in late 1957.)

18. Anon (news item). Factory converts garbage into fertilizer. *Civil Engineer* 26 (12) 93 Dec. 1956

> The new Orcoa plant at McKeesport, Pa., is pictured. It was erected and is operated under a contract by the Organic Corporation of America, Pittsburgh. The plant takes all the city refuse and transforms it into rich organic fertilizer in from 14 to 21 days. All material is pulverized in grinders and injected with special enzymes. "The entire operation is odorless and smokeless and involves no residue." Developed by the H. G. Burr Co., the Orcoa process is the result of over four years' research and experiment. (Ed. note: the plant was permanently closed in late 1957.)

19. *The McKeesport experiment with refuse composting. *Amer. City* 72 (9) 15 Sept. 1957 *Anon.

> The McKeesport plant has drawn nearly 4,000 visitors in almost 10 months' operation. Two Gruendler grinders shred the refuse, none of which is removed except rubber tires and heavy metal. Garbage content of the refuse is about 15%. The plant processes 70-80 T/day of refuse into 40-50 T/day of compost, sold as ORCOA, a soil conditioner. About 10 men operate the plant. The ORCOA sells for $2.69/50 lb. bag. Organic Corporation of America proposes to interest other cities to build plants with ORCOA operating the plant and marketing the product. The city will get a maximum of $1/ton from any net profit resulting from sales. "Apparently both the capitalized and operating cost of such a plant is somewhat higher than the cost of equivalent incinerator capacity." The Company lists a great number of trace elements in the compost but not N,P, or K. Company officials say that these will average about 1% each. Responsible city officials should ask:- 1) Can the plant receive *all* types of wastes?, 2) Does a compost market actually exist? If Pittsburgh does same?, 3) If product is not saleable, will the Company continue operation?, 4) If plant breaks down

19. (temperature) will it still be able to handle refuse withou nuisance or hazard?, 5) How will plant operate in cold or bad weather?, and 6) Will plant be unsightly, odorous?, 7) Are operating and cost figures on hand?

20. Anon. A new British compost mixer. Org. Gard. and Farm. 4,
(10) 56 Oct. 1957

F. A. Standen & Sons, Ltd., St. Ives, Hunts, England, has on the market in Great Britain a new compost mixer. Tests have shown that straw and other waste vegetation can be converted to finished compost in 2-3 weeks. Straw, weeds, etc. are forked into a feeder conveyor (drag type) which discharges them into a revolving drum where water is sprayed Drum action mixes water in and helps break up the material.

As the wetted material passes from drum to another conveyor phosphate, potash, limestone, or N-rich fertilizer can be added from a hopper mounted over the discharge end of the drum. These are also wetted with a fine spray of water. A third conveyor takes the materials to a spinner mechanism which breaks up the material further and aerates it. From the spinner, the material is thrown onto a pile until it is about 6 ft. high.

The machine is mounted on wheels and is called a "Standen-Hawkomatic Compost Mixer". It is driven by a 3 hp motor. It is 15 ft. 3 in. long, 4 ft. 2 in. wide, and 7 ft. 10 in. high. It weighs about 2,000 lb. Standen hopes to sell some in the U. S.

21. Anon. A new approach to municipal refuse composting. Amer. City (Typed advance copy, 4 pp received Dec. 12, 1957).

The Naturizer Company (Norman, Okla.) is developing a proces of composting municipal refuse in a mechanized plant. Norma Pierson (President) was responsible for collection and disposal of refuse from a city of 30,000 for 6 years. He then founded Naturizer Company 3 years ago. Originally windrow composting was used but the 3 weeks required was considered too long in terms of space requirements. Also turning was expensive and the windrows were influenced by weather conditions. The mechanized pilot plant has been in operation since Nov. 1955. Plans are completed and construction begun on a commercial plant at Norman.

The 6 stages of operation are: (1) Receiving and salvage with 24 hours storage; (2) Grinding and mixing - raw or digested sewage sludge or garbage may be mixed with dry refuse; (3) Decomposition occurs in digester cells for 6

21. days, the material dropping daily from one cell to the next; (4) Secondary grinding is done after 3 days of decomposition to reduce particle size; (5) Final grinding; (6) Screening, bagging, and storage with drying facilities.

Cost estimates are, for 150 T/day plant: Construction - $2,500/T of rated capacity (including building and office but not land); Production cost of compost - $3.04/Ton (including labor, fuel, building and machinery repair, State and City taxes, and some miscellaneous items); Salvage - $3.00 or more/Ton incoming refuse; Compost sale - $70.00/Ton bagged or $27.50/Ton bulk, f.o.b. the plant - sold as soil conditioner.

22. Anon. Earp-Thomas Continuous Flow Compost Digester. Pub. Wks. 88 (12) 138 Dec. 1957

A 50-ton/day Earp-Thomas composter can now be supplied knocked-down at Houston, Texas at an estimated shipping weight of 87,500 lbs. Output is about 2/3 of input but is made up to input weight by addition of "rock phosphate, vitamins, hormones, trace minerals, and secondary nitrogen-fixing bacteria in order to make a reinforced superior organic fertilizer." Local erection is recommended but a "trained engineering and erection crew can be sent to do the job." Additional equipment includes: a building, 70' x 45', storage bins, grinding hog ($5,000 to $8,000), a conveyor, an inoculating machine, and finished grinding equipment which "dispenses the rock phosphate, vitamins, hormones, trace minerals, and secondary nitrogen-fixing bacteria to make a finished reinforced organic fertilizer to the bagging." (Ed. note: There are no references to any but one conveyor, screens, sorting, drying, bagging, etc. and no cost data are given.)

23. Australian Institute of Agricultural Science, Victorian Branch, Conservation of City Wastes Subcommittee Report on the Conservation of City Waste. J. Aust. Inst. of Agr. Science 21 (3) 152 Sept. 1955

"Garbage can be composted successfully, with or without the addition of sewage sludge, and plants for its disposal by fermentation and sale as compost are in operation in many parts of the world, and are producing a satisfactory organic manure. On the other hand, many plants have closed down because of mechanical difficulties and high costs. The committee cannot recommend composting as an economical method of garbage disposal in Victoria, for the following reasons:

23. "(1) The composting plants which have been developed so far require a large labour force for hand sorting, and mostly present a dust and odour nuisance in closely settled areas. Moreover, the capital cost of installation is very high.

"(2) Composting would be an additional charge on the cost of garbage disposal, and farmers would not be prepared to pay a sufficiently high price for compost to cover this extra charge.

"(3) Moreover, the method at present used of tipping and covering garbage is satisfactory, and there are sufficient tipping sites within the Melbourne Metropolitan area to satisfy the demands of most municipalities for many years."

24. Bould, C. The preparation and nature of town's refuse-sewage sludge composts. *Inst. of Sewage Purif.* (presented Nov. 30, 1945); Abs. *Sew. Wks. Jour.*, 18, 1250-3 Nov. 1946

Liquid sewage sludge and pulverized town refuse were composted at Maidenhead in open cells 5' x 5' x $4\frac{1}{2}$' deep. Cells were of concrete with 2" boards on front. Layer of refuse was covered with sludge then with more refuse. After surplus water from sludge (93.5-94.7% H_2O) was absorbed (3-4 days), cells were emptied, materials thoroughly mixed and replaced. Sludge was added to bring the moisture content of mixture to 50, 60 and 68%. Refuse had initial moisture content of 33.7-45.9%. Composts with 50-60% moisture had good texture, were free from smell and could be bagged. They had a moisture content of 32%. Compost with initial moisture of 68% appeared sticky and smelled strongly of sludge, stickiness still noticeable after 14 weeks. Temperatures of 50-60% composts rose rapidly to a maximum of 76° C. three days after mixing. Temperatures of 68% moisture compost did not exceed 55° C. Aeration was accomplished by 3 in. drain tiles or filter bed tiles in base of cells. The addition of N as $(NH_4)_2SO_4$ dissolved in sewage sludge (0.1% N - dry weight of refuse) caused increase in temperature of 3-4° C. but had no significant effect on rate of decomposition. Addition of phosphate as $CaPO_4$ added to sludge (0.2% P_2O_5) gave a small increase on rate of decomposition over a period of 2 weeks N analyses:

% Moisture	Wet wt. Ratio*	Dry wt. Ratio*	N from (lbs.)		Total N	
			Ref.	Sludge	% Dry Wt.	% Volatile Wt.
50	3.5	82	20.37	0.87	1.22	3.02
60	1.5	34	19.47	2.06	1.27	3.12
68	0.95	20	20.05	3.62	1.33	3.23

*Ratio = Refuse/sludge.

24. Aerobic digestion continued for 5 weeks, but recommend only 2 weeks to cut down N loss, followed by 1-2 months of anaerobic storage. Finished composts gave: N - 0.88-1.50%; P_2O_5 - 0.83-1.40%; K_2O - .30-0.60%; Ash 50-60% (dry weight).

25. Brenner, Donald. High rate composting may solve refuse disposal problems. Pub. Wks. 88 (12) 156 and 158 Dec. 1957.

Recent field tests of the "Depurater", a multiple-stage composter, demonstrated its ability to handle a mixture of community refuse and garbage in a 3-week trial period under general direction of Prof. (Dr.) Wm. E. Dobbins and Dr. Gail P. Edwards of N.Y.U. The raw materials (normally incinerated) were thoroughly ground and mixed before being fed into the composter. The detention time was tested by means of plastic chips and found to be 3 days but the actual running time was only 24 hours as the plant was shut down at night. Average compositions were:

Raw material:- Inert (mostly glass and cans) 22% by weight; Paper, wood, etc. - 50%; food wastes - 28%; pH 4.7-6.4 (average 5.4); moisture 42.4-66.1% (average 54.2%); Volatile solids - average 72.2%.
Finished product:- pH 6.6-8.5 (average 8.0); moisture 41.5-59.2% (average 51.5%); volatile solids - average 60.6%.

The process resulted in a high reduction of coliform bacteria. Filtrates from raw and finished materials showed BOD results much less (about 1/3) in the finished compost. Disposing of the product in landfill offers the following benefits:

1) Reduction in windblown paper, etc. in handling at site;
2) Better compaction - less volume;
3) Less settlement;
4) Leaching water would be less objectionable;
5) No tendency to attract rodents.

Compared to open composting, that in the Depurator would: 1) eliminate weather conditions and exposure to rats; 2) Produce no objectionable odor (totally enclosed); 3) Involve no costly turning as this is accomplished automatically; and 4) Reduce land area because of composting time factor. (Ed. note: Personal communication indicates that Eastern Depuration Works, developer of the "Depurator", is headed by Mr. Martin Davidson, Box 36, Lawrence, Long Island, N. Y. Location and description of the plant were not given.)

26. British Med. Jour. (Leading article). Composting of household waste. British Medical Journal pp 758-760 Sept. 29, 1956.

Total amount and organic fraction of refuse varies. California reports 1-4 lb. per cap./day of mixed refuse; Great Britain about 1.5 lb. Compostable part varies from 70% to less than 10% in coal-burning countries in winter (e.g. Britain).

In last few years investigations into optimum conditions for decomposition of wastes have been made in Europe, India, China, S. Africa and U. S. Four papers are briefly summarized. In (1) about 2/3 of the C present is converted to CO_2 with release of energy, 1/3 utilized with N in synthesis of microbial protoplasm. Aerobic decomposition is very rapid. Anaerobic decomposition results in CO_2, methane and H_2S. Optimum moisture (aerobic) is 50-60% and this is lower than the 70-80% recommended for composting farm wastes containing much straw. Moisture must be controlled.

Usually only the portion remaining after removal of metal, rags, and glass and after screening out fine dust is composted. In Holland compost is produced first with later screening and pulverizing. Prior shredding is better and efficient crushers, rasps, or shredders have been developed. Modified bulldozers have been used for turning and mixing composts and Gotaas describes a conveyor-type turning unit with which one man can aerate, moisten, and turn 100 T/hr.

Organic matter is decomposed by a mixed flora of bacteria, actinomycetes and fungi, developing in different stages. Inoculation is not needed (2). C/N of less than 30:1 is desired with end product of 15:1. If initial C/N is low as much as 40% of N may be lost as NH_3. N losses can be held to less than 50% by mixing low-N with high-N materials. High temperature (65° C.) kills common pathogens and parasites and Gotaas believes none survive aerobic composting. Temperature also destroys weed seeds and reduces flies. There are no cases of disease recorded in Great Britain arising from use of habitation waste in agriculture (3).

Anaerobic decomposition oxidizes less C so less N is needed. Temperature does not increase much and pathogens are killed more slowly. The CH_4 can be used. One ton of organic matter yields 50-70 cu.m. of CH_4 and only 2 cu.m. are needed by the average family/day for cooking.

Commercial horticulture composts are usually stored 8-12 months; municipal only 2-3 months. Approximate composition of composts is:-

26.

Materials Composted	H_2O %	Dry Matter %			
		N	P_2O_5	K_2O	Ash
Garbage and Refuse, USA	-	1.4	1.1	0.8	37
U.K. Sewage sludge-town ref.	40-50	1.0	0.9	-	70
Refuse, Holland	20-35	.4-.5	.4-.5	.4	75-80
Farmyard manure	74	2.2	1.6	2.0	36

Refuse composts give lower yields in field trials than farmyard manure, particularly with preliminary hog feeding (3). The Zuckerman Report (4) concluded that 25,000 tons each of N, P_2O_5 and K_2O/annum is in town refuse in Great Britain but that less than 3/4 of this is in fine dust not economical to compost. Town wastes and sewage composted would produce only 2% of the N used each year in inorganic fertilizers. Effective conservation of sewage N appears more important than recovery of N from town's wastes. Ref. (1) Gotaas, Composting, etc. *WHO* 1956. (2) Golueke, Card and McGauhey *Appl. Microbiology*, 2, 45-53, 1954. (3) Agr. Res. Council, *Tech. Comm. #7*, Min. of Agr. & Fishy's Agr. Use of Sew. Sl. & Sl. Composts, 1948. (4) Nat. Resources (Tech.) Comm. Use of towns wastes in Agriculture. 1954. HMSO, London.

27. Brunt, L. P. Municipal Composting. *Municipal Engineering* 124, 80-82 Aug. 12, 1949

Composting of town refuse and sewage sludge by Indore process is with aeration and moisture control. Paper will decompose but is usually excessive in relation to other compostable substances in garbage. Materials removed from garbage are tires, bottles, broken glass, scrap metal, rubble. Abattoir wastes make a valuable contribution to compost. Whole carcasses can be placed in the heaps. Some trade wastes, as sawdust and those from canneries, are excellent, in due proportion, for adding to compost; as are sewage screenings. Sewage sludge brings moisture content up to the most favorable level. Uniform small fragments are desired but not so small as to pack into a dense mass that air cannot penetrate. Grinding is by a shredding machine in which hammers rotating at high speed smash and tear the garbage, bones, etc. Sludge is sprinkled over shredded materials at intervals as the heap is being built up. Three-sided compartments or sunken pits are composters. Aeration is by turning at intervals or forced aeration from bottom. Turning may not be necessary if the heap is built right. Smallest practical size of shredder has a capacity of 1 ton/hour. For small installations, no ventilation is provided in the first heap as sludge would drain away.

27. Sorting at larger installations is best on a rotary screen with a magnetic separator for Fe and a belt conveyor to shredding machine. Drainage from sludge addition is returned to the sewage plant. Heaps should be formed loosely as from a belt, rather than by bulldozer or mechanical shovel which tend to form lumps. Optimum moisture in the heap is 60%. If average moisture of shredded wastes is 25% the amount of sludge is 0.9 times the weight of wastes. Subsequent additions of sludge depend on weather. In Great Britain sludge-refuse weights should be about 1.5 to 1. If there is too much liquid sludge, part may be dried but later added to compost from drying beds. Compost loses about 20% of its weight. Time required is 60 days, at least. Space required is based on 1 ton = 2½ cu. yd. Humus is sold for 20S/ton.

28. Burke, Charles E. Utilization of organic domestic wastes. The Surveyor 108, 629 Oct. 21, 1949 Discussions - ibid. 108, 655 Oct. 28, 1949 108, 665 Nov. 4, 1949 and 109, 161-163 Mar. 17, 1950

Cost computations are made on a composting plant for household refuse and sewage sludge for a city of 557,640 on the basis of a report by C. C. J. Bullough in 1942 based on a city of 50,000. Estimates are refuse 140,000 tons and sewage sludge 6,022 tons (dry basis) per year. Plant includes receiving hoppers, separation, pulverizers, composting bags, and maturing grounds. Ten days are provided for in composting bags and 22 weeks in maturing grounds. Annual costs are estimated at $226,348 not including taxes, administration, or land acquisition.

Estimated income:

Material	Tons	Price	Amount
Dust & fine ash	59,920	$ .20	$11,984
Cinders	15,260	.50	7,628
Paper	6,160	28.00	172,480
Ferrous metal	3,360	2.30	7,728
Non-Ferrous metal	28	200.00	5,600
Rags	350	96.00	33,600
Bottles	574	24.00	13,776
Cullet	308	3.00	924
Compost	60,062	1.80	108,108
Total	146,022		$361,828

Discussions: It does not appear practical to give up the income from paper by composting it.

28. Conditions have changed since 1942. At Maidenhead, revenue did not pay for the costs of production. However, the method is still practical if costs are less than other methods.

Composting has been conducted at Maidenhead for 13 years and at Leatherhead for 12 years; also in a number of small cities in S. Africa, New Zealand and Central America.

Burke considers the composting of sludge and household wastes to have limited application. He pointed to the high costs of a sorting plant. The paper proposed a scheme of composting sludge and refuse for a city of 500,000. On a dry solids basis only 23.7 tons of sludge can be added to 220 tons of refuse. J. Stanbridge (Maidenhead) believes it necessary to have tips (landfill) and also that it is difficult to dispose of the amount of sludge along with refuse from a town by composting. Brunt (Mitchell Eng'g. Co.) claims good compost is more valuable than separately screened dust, pulverized garbage, or dried sewage sludge as they require slow transformation in the soil before becoming available as plant food. He also claims that pathogenic organisms are largely killed by high temperature and the development of antagonistic organisms. Brunt thinks costs will be more reasonable for a population of 50,000 instead of 500,000. H. H. Stanbridge (Epsom & Ewell) is for separate treatment because: (1) not all of refuse is compostable, requiring a landfill; (2) from the same population there will be a surplus of sludge; (3) compost is needed seasonally requiring a large storage area. It was pointed out that refuse in England still does not include kitchen wastes which are collected separately for hog feeding.

29. Univ. of Calif., Sanitary Eng'g. Research Project. Composting for disposal of organic refuse. Tech. Bull. No. 1, Inst. of Eng'g. Res., Series 37, 42 pp July 1950

This Bulletin, prepared in conjunction with a bibliography on composting (Bull. No. 2), analyzes past and present knowledge of the subject. Due to the increasing population density and other factors, the subject of composting as a means of both refuse disposal and reclamation is reopened as a consideration for American city refuse treatment. Topics covered are: 1) Nature of composting; 2) Composting processes, (a) Traditional, (b) Indore, (c) Beccari, (d) Verdier, (e) Frazer, (f) Earp-Thomas, (g) Dano, (h) other aerobic-anaerobic, and (i) Anaerobic; 3) Economics of composting; 4) Investigations required; 5) Conclusions. There are 4 appendices. Conclusions are:

29. 1.) Practically all types of organic wastes have been successfully composted;
2.) Composting is the most desirable method for disposing of garbage from reclamation and soil economy viewpoints;
3.) There is a dearth of engineering data, especially cost data, and very little analytical data on the basic factors involved in the composting reactions;
4.) A research investigation /Ed. note - see Bull. 9/ should be undertaken to establish the required design data by a) laboratory-scale study, and b) pilot-scale studies.

30. Univ. of Calif., San. Eng'g. Research Proj. Bibliography on disposal of organic refuse by composting. Tech. Bull. No. 2, Inst. of Eng'g. Research Series 37, Mimeo. 80 pp Aug. 1950

From nearly 3,000 references, this bibliography containing 610 selected articles and patents on composting was prepared after a critical review of the literature. Sources of references were mainly: Chem. Abs., Ind. Arts Index, Eng'g. Index, World Bibliography of Bibliographies, and private papers of Charles Gilman Hyde. Initially 75 general references are cited. Most of the 538 references to journals have very short abstracts; the patents have not been abstracted. Listing is alphabetical by principal author. There is a key to abbreviations and a subject index.

31. Univ. of Calif., San. Eng'g. Research Project. Reclamation of municipal refuse by composting. Tech. Bull. No. 9, Series 37 89 pp June 1953

(Ed. note: This bulletin reports on the first really basic research done on composting in the United States and is a highly recommended reference for anyone interested in the composting of organic wastes.) Studies included 1) literature review (see Tech. Bull. No. 1 and No. 2); 2) laboratory studies; 3) pilot plant investigations; 4) field studies; and 5) miscellaneous studies on: a) the fly problem, b) special inoculums, and c) grass clippings and garden refuse. Studies (2) and (3) involved the use of synthetic garbage or refuse, largely shredded vegetable trimmings and straw or paper, whereas the field studies (4) were conducted at the City of Berkeley sanitary landfill using segregated refuse from that City. All studies were concerned with aerobic, thermophilic decomposition of organic wastes in jars, bins, piles, or windrows, rather than in closed mechanical units. Small laboratory units (5-gal. and 55-gal. capacities) were held in incubators generally at 50° C., but larger masses (pilot studies in 40" x 40" x 60" high bins) were composted in an unheated

31. warehouse. Field studies were done in the open in 2- to 4-ton piles. Various physical, biological and chemical factors were studies and summarized in Chapter III - Fundamentals of composting and general, economic, and design considerations. The summary and conclusions itemize 58 principal findings obtained from the studies, some of which are:

1) Composting should be considered as a means of disposal and reclamation for municipal refuse.
2) Factors fundamental to aerobic composting are: initial population of microorganisms, available nutrients, temperature, hydrogen ion concentration, moisture, and aeration.
3) The microorganisms are indigenous to municipal refuse so that inoculation, seeding, re-cycling, or other additions are unnecessary.
4) Normal city refuse has the nutrients needed for composting. More rapid composting occurs at C/N ratios of 30-35 than at 50; below 30 nitrogen is lost. The ratio may be readily adjusted, if necessary (Berkeley refuse averaged 33).
5) Temperatures of 50 to 75° C. are attained during composting, sufficient to kill pathogens and flies.
6) Hydrogen ion concentration is not limiting for municipal refuse. Lime may speed composting but results in loss of N.
7) Optimum moisture for municipal refuse is between 40 and 65%. High moisture may be reduced by daily turning and aeration or by addition of dry waste. At optimum moisture, turning every 3 days may be adequate.
8) Aeration is essential but the organisms require relatively small amounts of oxygen. Turning is the best means of aerating.
9) Windrow composting of refuse can be accomplished in 12 to 21 days provided the refuse is previously ground and the windrow is turned and aerated at intervals. No fly or odor problems exist. Other organic wastes than city refuse, such as sewage sludge, cannery wastes may be composted with refuse.
10) Humus as obtained from composting municipal refuse benefits the soil in many ways as well as by adding plant nutrients and trace elements. (Ed. note: See also 32, 41 and 42.)

32. Card, Bradley, and Gotaas, Harold B. Composting organic refuse from municipalities. Western City 29 (3) 30-34 Mar. 1953

Discusses various composting processes, indicating that the traditional and Indore processes are usually accompanied by objectionable odors and fly breeding, and are quite slow (anaerobic decomposition). Modern composting is aerobic (principally thermophilic). Major factors influencing

32. the activity of organisms are: particle size, moisture, aeration, temperature, pH and initial C/N ratio. Sufficient aeration to permit aerobic action results in increased temperatures (caused by increased bacterial action), elimination of foul odors. Excess O_2 is not beneficial because aeration accelerates the biologic stabilization process only whenever O_2 is limiting.

Laboratory investigations of Sanitary Engineering Research Project (U. of California) were made of 7 lb. batches, 55-gal. drums containing 140 lbs., and bins containing over 1 cu. yd. of refuse. Field investigations were with batches of 2 tons of mixed refuse in Berkeley. Included were experiments with refuse plus raw or digested sewage sludge.

Average composition of refuse composted in field studies was: tin cans - 9.8%; bottles, broken glass - 11.7%; rags - 1.6%; metals -0.9; waste (no value) - 7.6; compostable materials - 67.7%. Ash was 28.5%; moisture - 49.3; C - 35.7; N - 1.07; P_2O_5 - 1.16; K_2O - 0.83; C/N = 33.8 (chemical determinations were made after segregation and grinding). C/N varied from 20 to 78; N - 0.5 to 2.0%; P_2O_5 - 0.6 to 3%; K_2O - 0.4 to 1.5%; moisture - 40% (for mixed refuse with much paper) to 90% (wet garbage). Shredding to pass 1½" mesh screen was accomplished after picking. Average initial and final chemical analysis (% dry basis):

	Initial	Final
Ash	27.59	43.63
Carbon	36.40	27.85
nitrogen	1.09	1.18
Phosphorous	0.20	0.30
P_2O_5	0.91	1.33
Potassium	0.27	0.39
K_2O	0.83	0.99
C/N	33	23

Steps required: (1) Segregation of metals, ceramics and non-compostables; (2) Grinding; (3) Maintenance of proper moisture content; (4) Stacking in windrows for composting; (5) Aeration by turning; (6) Final grinding (if desired).

C/N ratio: High ratio increases the time required because all of N is converted to cell material and these cells have to die requiring several life cycles before stability is reached. Low ratio will result in release of N as NH_3 which would escape to the air. Optimum initial C/N should

32. be 35; above 30 to avoid loss of N. The normal city refuse is believed to be satisfactory for proper C/N. Optimum moisture is 40-60% but 70% can be handled if straw or other material is added to prevent soggy compaction. More frequent turning is required at above 60% moisture (turned every 3 days at Berkeley). Temperature drop during turning was 8-15° F. and was recovered in 2-3 hours. Simple overturn or vertical expansion of piles is insufficient in turning; need an inward mixing of material from outside of piles. Inoculums are not essential. Time required: C/N = 20, 14 days; C/N = 20 to 50, 16 days; and C/N = 78, 21 days. Sludge may be added directly after grinding in alternate layers. Compost is considered finished when it does not heat in piles (persistent drop in temperature), final C/N is 12 to 20, color is gray-black to brown (color is not a good criteria). Estimated production cost is $12-$15/ton which may be higher than selling price. Need a grinder that will handle metals and glass.

33. Davey, C. B. Sawdust composts: their preparation and effect on plant growth. Soil Sci. Soc. Am., Proc. 17, 59-60 1953 Chem. Abs. 47: 7718h 1953

In order to decrease the C/N ratio of sawdust treated with NH_3, H_3PO_4 and K_2SO_4, it was inoculated with Coprinus ephemerus. Within 3 months this organism converted sawdust to a finely divided dark brown material which resembled a rich mull-like soil in appearance. The composted sawdust produced marked increases in growth of both coniferous and deciduous seedlings and medium red clover on sandy soil (Wis. State Agr. Exp. Sta.).

34. Dawes, J. C. The storage, collection and disposal of domestic refuse (including garbage) in the U.S.A.--Report, with observations and recommendations. Ministry of Health (London) Mimeo. 20 pp, January 19, 1950 (Reprinted by Public Health Service).

This British Engineer was commissioned by the World Health Organization to act as technical consultant in the field of refuse disposal and this is his report on conditions observed in the U. S. Only the parts on grinding, pulverization, rapid fermentation, and composting are covered here. The grinding of garbage with discharge to the sewers loses whatever value the raw material may have as feed or humus-former. Sewers which receive ground garbage and discharge to rivers increase the risk of pollution. Use of the grinding process depends on local circumstances such as capacity and suitability of sewers and sewage treatment plant.

34. Pulverization is another form of grinding, the idea being to convert mixed refuse into a soil improver and humus-former. The machines may be of cutting or hammermill type, generally the end product passes a 3/4" to 1" screen. (Ed. note: This means of disposal is practiced in Great Britain and Europe, but not in the U. S.). U. S. refuse has high putrescible matter and low mineral content and may give rise to fly and rodent infestation if stored in substantial quantities. Author recommends that USPHS set up a small committee of Sanitary Engineers, Soil Conservation experts and Zoological Division representatives to examine this method where soil conservation and enrichment might follow the application of pulverized refuse.

Rapid fermentation (Ed. note: decomposition in sealed cells) requires a costly plant to hold the refuse for a period at temperatures which speed up fermentation so that the end product is a useful humus-former or soil-improver. U. S. refuse seems to have a high fermentable content but also a high paper content. Presence of paper in the end product would tend to "lock-up" some of the nitrogen made available by the organic matter. The value of the fermented product should be calculated on the average percentage of fermentable material present in the raw refuse and not on the tonnage of refuse to be handled, much of which is worthless. It is also necessary to consider the outlets for the end product - ascertain that they will be safe and sure.

Composting (Ed. note: this is apparently windrow, pile, or bin composting) is a well-known method of breaking down the putrescible content of domestic refuse and might be comparatively cheaply used to advantage, especially in smaller cities, given suitable soils, to meet local demands for a low price humus former or soil improver. Very little plant is required but the high price of manual labor sometimes makes the process uneconomical.

35. Duchon, Frantisek. Contributions of the Czech. evolutional research to conserve and increase fertility of soils. *Vestnik* Ceskeslov. Akad. Zemedelske 24:312-24, 1950; *Chem. Abs*. 44:9605a.

"Biothermic fermentation of many waste matters produced humus fertilizer as good as stable manure in chief animal nutrients and trace elements and superior in microfora and plant hormones."

36. Dymond, G. C. The increase of available phosphate in rock phosphate by composting. *S. African Sugar J.* 35; 467, 1951; *Chem. Abs*. 46:31971.

36. "Composting increases the availability of P_2O_5. The agricultural value of enrichment of garbage and sewage wastes with rock phosphate is indicated."

37. Earp-Thomas, G. H. Earp-Thomas Continuous Flow Digester. Pamphlet 75 pp, Earp Laboratories, Hampton, N. J. Undated.

Waste organic matter is freed of metal and glass and ground; goes past an inoculating machine to hopper of digester. Material is discharged to digester through a trap door. The digester has preferably 8 tiers or stages. Material in first stage is moved by plows from outside to opening in center where it drops to second stage. In second stage material is moved by plows to periphery and down through an opening into the third stage, etc. Material emerges from counter-weighted door of eighth stage as decomposed compost. No. 1 depuration bacteria are added at a rate of 1 oz./3 tons (cost is $1.50 per oz.). The first stage may have a slotted screen and waste water pipe to discharge excess liquid to bottom of tank. The last 3 stages have bar screens, instead of solid plates for bottoms, to hasten drying, and with progressively smaller openings. Warm dry air is supplied and a fan draws off excess moisture. A photo shows a 6-ft., 6-floor digester, power required - ½ HP.

Cost data - Plant for 100 ton sewage sludge or screening per day having 60% moisture will cost $45,000. It will produce 45 tons/day of compost at 12% moisture. Cost of production: Humus $20.00; lime $1.50; reducing bacteria $78.75 per day; labor - 5 man-days at 50¢ per hour = $20.00; depreciation - 10 years at 300 working days per year - $15.00; power 200 kw at 2¢ = $4.00; total cost = $139.25 or $3.06/ton.

The temperature during the process passes 150° F. and may go as high as 170° F., thus pasteurizing the garbage or other material. (Ed. note: Although several Earp-Thomas plants have been constructed, no plant for municipal refuse or garbage, with or without sludge, treatment is known to be operating in the U. S. today. Some foreign operations are claimed, such as: France-Condon, Ramboullet, Talleraf, Moget, Courfouleux, Mariel, Bexiers, and Paris; Morocco-Casablanca; Canada-Toronto; Australia-Sydney. Former Earp-Thomas type plants in the U. S. were at Twin Falls, Idaho; Chicago Stock Yards; East Lansing, Michigan (see 75 and 76.) (Ed. note: In a recent visit to Chicago, it was learned that there never was an E-T plant at the Chicago Stock Yards.)

38. Eng'g. News-Record (Editorial), Composting provides no panacea. Eng'g. News-Record 150(22):112, May 28, 1953

A recent discussion of "where composting stands" stated: 1) "It has not yet been proved that composting can be justified on the basis of waste recovery alone." 2) "Less progress has been made in solving the mechanical problems of composting than in understanding the biochemical process." This was discussed by Richard P. Kennedy, San Francisco consulting engineer. Recent operating troubles on Long Island (Frazer-Eweson plant at Bay Shore) emphasizes the second statement. Segregation of wastes is expensive, grinding is a severe strain on available grinders, and metals are readily corroded by moist garbage. So far, there is no proved means of making waste disposal pay. Engineers should consider all methods of disposal and choose composting only when it proves itself economically advantageous over other effective methods.

39. Eng. News-Record. 1949-50 Annual Report on Techniques and Trends, Refuse Collection and Disposal. Eng. News-Record 144: 124, Mar. 23, 1950

Design and construction of refuse collection trucks and incinerators is improving with disposal of residue being planned for in landfills. Many former open dumps are being converted to semi-landfill. Hog-feeding farms are expected to disappear gradually because of extreme nuisance Landfill practices are improving due to more efficient operation and engineering planning. Composting and digestion methods of disposal may be proved or discounted by projects underway. These methods only dispose of the organic materials requiring other procedures for non-combustibles and inorganic refuse.

40. Eweson, Eric. Composting of Garbage and Sewage Sludge. Amer. Soc. Civ. Engrs. Separate 312, 8pp, Oct. 1953

Need for (1) adequate method of disposal of wastes to avoid pollution, and (2) returning organic matter to soil to avoid impoverishment is stressed. Composting organic wastes to humus solves both problems. Claimed that temperatures of 160-170° F. in compost destroy all pathogens. The amoeba cyst (most resistant of pathogens) is completely killed at 122° F. Humus has appreciable fertilizer value with N,P,K all available and not subject to leaching, in addition to beneficial microorganisms, does not burn seeds or roots, and contains no inert filler. By modifying composting can get N,P,K of $2\frac{1}{2}$-5-3 in compost, which has value of chemical fertilizer of 5-10-6.

40. The Frazer-Eweson plant is described: 5,000 cu. ft. digester, 30 ft. high with 5 zones having grids between. First 4 are fermenting zones, 5th is unloading zone at bottom. Aeration is by forced recirculated air with some bleeding of air between zones by vents just beneath grids. In lowest zone air contains 0.05% CO_2, 4th zone 1-2%; 3rd zone 2-4%, 2nd zone 8-10%. It is claimed that heated air (heated from passing through hot zones) containing high moisture and CO_2 provides best environment for the bacteria. CO_2 forms H_2CO_3 which renders soluble some water-insoluble nutrients needed by the organisms. Temperature increases from 80° to 170° in middle zones. Ground limestone may be added to produce neutrality and other ground rock materials from which minerals are liberated. Raw materials are sorted and ground (garbage, sludge, other organic wastes); finished compost (7 days) is dried over vibrating screens, the 10% tailings being returned. No drainage problem. Cost of 25 ton plant (2 digesters) is $100,000. Plan shown. (See 10.)

Furbank, Arthur W. Discussion - Stabilization of municipal refuse by composting. Am. Soc. Civ. Eng. Proc. Paper No. 481: 9-10, Aug. 1954 (See 73.)

41. Golueke, C. G.; Card, B. J.; McGauhey, P. H. A critical evaluation of inoculums in composting. Applied Microbiology 2: 45-53, Jan. 1954

This reports results of laboratory and pilot scale experiments at the University of California using horse manure, composting material, bacterial cultures, and soil as inoculums for compost in batch process. The only new information, not given in Tech. Bull. #9 (31), is the medium used in culturing organisms. Conclusions were that no measurable effects resulted on the course of temperature, increase in % ash, or decrease in % carbon, as a result of the addition of any inoculum. It is suggested that an adequate bacterial population already exists in the garbage. Method of cultivating thermophilic actinomycetes from inocula is as follows: 1 gm. of each sample was diluted $1:10^3$ in sterile distilled water. From each dilution 1 ml. portions were transferred to sterile petri dishes and poured with starch-asparagine agar (starch, 10.0 g.; KH_2PO_4, 0.5 g.; asparagine, 0.5 g.; agar, 15 g.; H_2O to 1 l.). One-ml. portions were also poured on the surface of starch-asparagine agar contained in sterile petri dishes. Plates were incubated at 50° C. for 5 days to simulate the temperature range suited to thermophilic actinomycetes. Counts obtained were as follows:

inoculum (typical commercial preparation) - 15.8×10^7/g
"rich" soil - 13.4×10^7/g.
"poor" soil - 15.8×10^6/g.

41. These were reported to compare favorably with the 15.7 x 10^7 colonies/g. reported by Waksman in horse manure.

42. Golueke, C. G. and Gotaas, H. B. Public health aspects of waste disposal by composting. Am. J. Pub. Health 44:339-348, Mar. 1954

Present refuse disposal methods are unsatisfactory generally from the standpoint of health. Composting stabilizes organic matter by biological decomposition, producing a humus useful to agricultural soils. Outdoor composting of refuse is described briefly and reported to require 10-20 days. Compost is produced by aerobic thermophiles with compost temperatures rising to 70-75° and persisting for 3-6 days. It is claimed that these temperatures destroy pathogens, insect eggs, larvae, and pupae. Finished compost from municipal refuse contains 1.2-1.6% N and less than 1% of P and K. Physical effects on soil are as important as nutritional effects. Both raw and digested sewage sludge and municipal refuse composted satisfactorily without much odor or flies. Limiting is the moisture content of the mixture which depends on initial moisture of the sludge.

Public health aspects: No health hazards have been reported from abroad. The thermophilic temperatures should kill all pathogens if the compost is properly turned to expose all parts to the high temperature. Fly larvae are also killed. At least 3 turnings are desirable. Eggs of ascaris lumbricoides are destroyed by thermophilic digestion at 53-54° C. Carelessness and breakdowns are to be avoided, particularly if raw or digested sludge is used.

43. Gorby, Harry B. Windrow Composting. Personal communications June, July 1957

A process of windrow composting of organic wastes is being developed by the American Dross Disposal Corp. of Oklahoma City embodying the following general plan: 1) No general pre-sorting is done. Large items are removed but tin cans, glass, and ceramics are removed by screening after composting is accomplished. 2) No separate conveyor is necessary. The material is windrowed and the windrow is turned by an integrated, self-propelled pick-up, conveying, moistening, and shredding device all in one operation. The unit being developed for this is called the "Gorbage Hog." It operates on tractor-type tracks and carries a special pick-up device, front-to-back elevating conveyor, shredder, and 500-gal. water tank. 3) Turning frequency is determined to a large extent on the physical condition of the materials

43. being composted. Wind and ambient temperature have little effect on the process but turning in cold weather will inhibit the process in some degree. Turning will generally be done every 3 to 4 days and total composting time is about 15 to 18 days, under ideal conditions only 10 days. 4) A more stable end product will result if the compost is "cured" in piles. Actinomycetes flourish in the undisturbed material and a higher degree of cellulose decomposition is attained if the compost is cured. 5) The final compost is screened in a 2-stage screen, re-ground (if necessary), dried to less than 35% moisture, and bagged. The Company indicates that dehydrating in a triple pass dryer and bagging in a three-ply Kraft bag is less costly than no drying but bagging in a 5-ply lined bag. 6) Windrows, for all-weather operation, should be on a hard-topped area. On soil, there will be a considerable amount of soil in the end product. No building or roof is required over the windrow area; only for the storage and bagging areas. Snow fences should be used when blowing paper is a problem but fly screening of the windrow area is not needed. 7) Either raw or digested sewage sludge may be composted with refuse if the moisture is not too great. Raw sludge is better because of higher N content. Greater frequency of turning may be needed because of finer particle size resulting in decreased aeration over that with refuse alone. Ferric chloride treatment of sludge may tend to inhibit composting.

44. Gotaas, Harold B. Composting - Sanitary disposal and reclamation of organic wastes. World Health Org. Monograph Series No. 31: 205 pp, 1956 (Palais des Nations, Geneva, Switzerland, $5.00)

(Ed. Note: This monograph is the most complete and worthwhile text on the subject of composting of organic wastes. It is not possible to summarize the lengthy text in an annotated bibliography such as this. About all that can be done is to show the scope by listing the various chapters and to recommend that all who are interested in composting obtain a copy of the complete monograph as a reference.)

Chapter Headings: 1) Decomposition of organic matter; 2) Sanitary and agricultural importance; 3) Historical development; 4) Raw material: quantity and composition; 5) Fundamentals; 6) Methods and planning for cities; 7) Methods for villages and small towns; 8) methods for individual farms; 9) Manure and night-soil digesters for methane recovery on farms and in villages. Indexed. 49 figures, 10 tables, 94 references.

45. Grindrod, John. Mechanical composting of garbage and sewage sludge. Public Works 87(6):119-121, June 1956

The mechanical (rotary drum) composter called Dano Bio-Stabilizer treats garbage and sewage sludge, stabilizing the material in 3-5 days. It has no grinding parts, low labor requirements because of fully automatic handling. A rapid drop in CO_2 production is attained after 3 days and trials were made of compost in germination and plant growth beds (1 part soil, 1 part compost). Results showed good after compost was 3½ days old. Forced air is supplied and optimum temperature is 110-130° F. Inoculations and addition of lime proved to be of no value. Temperatures of 150° F. can be obtained as required. There is no pregrinding or sorting. The grinding during composting is claimed to be only by internal friction, not by tumbling. Compost is screened and tailings (which are inoffensive) are then sorted. The heat produced is proportional to the CO_2 and will tend to dry out the materials unless additional H_2O is added. Wet sewage sludge can be used to provide H_2O and to provide the addition of organic N. Digested sludge with 90% or less H_2O is used and can be added to its own weight of refuse. The first plant (outside the factory) was at Rüshlikon, near Zurich; 5 tons/day. A 20-ton plant was built at Edinburgh, Scotland, by the city. The Edinburgh plant has: receiving hopper, conveyor, rubber belt to feeding device (sewage sludge added), Dano biostabilizer, vibrating screen, conveyor belt to storage hopper to vehicles. Tailings are either recirculated by belt or transferred to incinerator. Design was for 5-6 day retention. Largest units are 50-75 T/day. The Edinburgh plant cost 36,000 pounds and started July 22, 1955; is operated by one man. It had some trouble with gear teeth. From 20 tons of refuse with 150 gal. sewage sludge/ton, got 14 tons of compost and 6 tons of inert, rejected materials. Compost is sold at 2 pounds/ton, good market. Feeding chute was found to be too small for large tailings. Modifications proposed are: (1) larger inlet (2) cutting edges in inlet end of drum (3) 40% increase in capacity of drum /to handle tailings from other works7.

46. Grinnell, Russell. Compost made from wet sludge, wood chips and street leaves offered free to gardeners. Wastes Eng'g. 28(3):123-4, March 1956

A pit 250 ft. long x 50 ft. wide x 4 ft. deep was constructed on a knoll at the sewage treatment plant of Birmingham, Michigan. In the fall, leaves are piled along one side of the pit as collected by D.P.W. The city

46. Forestry Dept. uses a chipper for twigs and branches and these are put in with the leaves. When all leaves are piled, a bulldozer pushes the materials into the pit, spreading and compacting it. A 1,000-gal. tank truck hauls wet digested sludge to fill the pit to the brim. The mixture is allowed to compost for a year and the material is then dry enough for the bulldozer to push it to one end of the pit. A sign was installed reading: "Sludge - Help Yourself." The demand is such that the compost is removed by individuals by the following June. Sale was a bother and the revenue was small, but the free material creates good will towards the sewage treatment plant. This is also a simple way of handling sludge, leaves, and chips.

47. Gutteridge, Hal. Refuse-Sewage Composting. The Surveyor (Br.) 111(3162):645-6, Oct. 11, 1952

Sewage sludge and screenings may be composted with town refuse. At Southwark, London, the refuse is ground locally and transported to the compost plant. Twenty thousand tons of crude refuse are handled per year. It is composted with sewage screenings at the Northern Outfall Works. In Holland refuse is taken to the composter site and then treated (i.e. from the Hague, Groningen and other cities to the Wyster plant). The refuse is not ground or separated until after composting. Advantages of local refuse grinding plants: (1) short haul, (2) salvaging done early with saving in weight of later transportation, (3) pulverized materials are not attractive to flies, rats and other vermin because the water content is below that which they desire and there is absence of any vapors of putrefaction, (4) pulverized materials are more easily handled by automatic equipment and in transportation.

Suggests for city of 500,000:- 5 pulverizing stations (maximum haul 3 miles) of 100 tons each (crude refuse). Transport ground refuse to 3-4 compost stations outside city limits at existing sewage treatment plants or other sites. Cities of 25,000 might take refuse direct to a composting works. A central station might also be used for a number of small villages. Organic manures and chemical fertilizers are complementary, both are needed in the soil. Substantial portions of sewage sludge could be absorbed in the compost, thus reducing the amount to be treated in the sewage treatment plant.

48. Henderson, John M. Refuse composting in India. Pub. Wks. 88(11):99, 176-7, Nov. 1957

City of Indore, India (population 300,000) has 4 sites for composting of mixed municipal refuse and night soil. Three collections are made: Sewage (kitchen and bath) water, night soil, and street sweepings and domestic refuse (including garbage). Refuse is extremely dry and low in per capita yield (not much fruit and vegetable wastes); tin cans are almost nil and there is no practical salvage value in the refuse. Refuse is high in C, with negligible N; this is balanced by night soil with high N and H_2O contents.

Indore process is used at only one site. Consists of a pit 2-3 ft. deep x 10-12 ft. wide x 100 ft. long. Refuse and night soil are placed in alternate layers each 3 in. thick to a depth of 5 ft. The windrow fills only ½ of the trench width. The material contains housefly eggs and adults on arrival but they are effectively controlled by a single application of 2.5% solution of benzene hexachloride (containing 6.25% gamma isomer). Application is at a rate of 1 Imperial gal./1,000 sq. ft. Thereafter, composting action [heat] takes care of the fly problem. Compost is turned in the pits every 15 days for 2 months, then stored on the ground beside the pit for 1 month without turning. Thus, the Indore process requires 6 complete handlings of the material by hand labor.

The Bangalore process is used at 3 sites in Indore. Trenches 30 ft. long x 4 ft. wide x 4 ft. deep and the materials are placed in layers as above to a depth of about 18" above ground level and finally covered with 6 in. of earth. Materials are not turned and essentially anaerobic digestion occurs for about 4-5 months. Fly control is achieved by the earth cover and possibly by heat. Only 2 handlings are involved.

Average N of Indore compost is 1%, of Bangalore compost is 2%, but difference is due to raw material composition rather than N losses. Finished compost is hauled by farmers in carts, paying about 31¢/load of 40 cu. ft. (Bangalore; less for Indore). Annual revenue is $5,250. Indore process is not favored due to high labor required, even though labor costs only 32¢/day. Higher temperatures are reached in Indore process.

49. Hodgson, H.J.N. City refuse disposal and utilization. J. Royal Soc. for Prom. of Health (formerly Royal San. Inst. J.) 77(4):196-200, Apr. 1957

49. This is a summary report based on a tour by the author of Great Britain, Europe, and America in 1954.

I. England - The main disposal methods are incineration, controlled tipping (sanitary landfill), and composting. Incineration is not likely to increase because of high costs and difficulty in disposal of clinkers. Sanitary fill is the accepted method and there is little justification for any other. Composting support is "in the hands of a few whose figures are often suspect." Officials of the Ministry of Housing and Local Government argue against composting because the material is "poor, with much useless organic matter, and that organic matter can be more easily obtained from normal farming operations." The compost market is "uncertain and would grow more so if supplies increased."

II. Scotland - The greater interest here in composting is due to Wilson at Edinburgh and Wylie at Dumfries. Health officials "appear favorably inclined towards composting." A new D no unit is being installed at Edinburgh which includes salvage of rags, metals, clean paper, bottles, etc. Sites at Edinburgh for sanitary fill are scarce. At Dumfries there are three composting plants in the County (Barony, Dalscone, and Kirkconnel). The initial reason for composting was a sewage sludge disposal problem. Straw and grass are composted with sludge and the compost is sold as a low-grade fertilizer. Health authorities challenge the use of raw sludge. The plant at Kirkconnel received a large government subsidy.

III. Ireland - Several composting plants have been abandoned in favor of sanitary landfill.

IV. St. Helier, Jersey has approval of a composting plant due to a shortage of organic matter and the fact that two crops per year are grown. Estimated cost of production 4 pounds, 10s, od; sale 7 pounds 10s, od per ton.

V. In France and Switzerland the general preference is incineration.

VI. Holland is densely populated, essentially agricultural with a poor sandy soil, thrifty people. Refuse is of poor quality: food wastes are not included, few bottles, less ash. Over-all figures: 50% sanitary fill, 25% incineration, 20% composting. At Wyster, refuse from 700,000 is made into rough, low-grade compost. Compost is applied at the rate of 16 tons/acre, once every 4

49. years. The Schiedam process produces better compost (finer, but not of better fertilizer value).

VII. Denmark has a large cattle population and balanced agricultural system. Composting is most impressive, it being produced without nuisance and with minimum of labor. However, the cost cannot compete with sanitary fill.

VIII. Germany - Composting is not favored because of economics. Baden-Baden refuse is composted with digested sludge but the plant is quite insanitary.

IX. America - Incineration is used in large cities; sanitary fill in smaller ones. Kitchen grinders are increasing. Use of wet garbage as pig food is practiced. Composting does not exist on a commercial scale. Composting is discouraged by M. S. Anderson (USDA) and E. B. Bessilievre (Dorrco). Professors J. R. Snell and H. B. Gotaas are advocates of composting. The big question is "can the process be economically sound?'

X. General conclusions - 1) Most sanitary disposal of putrescible wastes is by kitchen grinder to sewer; leaves dry refuse to be collected; America leads; 2) Sanitary landfill is the most widely used and probably the most satisfactory; 3) Incineration is on the decline due to high cost of installation; 4) Composting is not widely accepted but is a possible alternate to present methods and a means of waste recovery. Factors deterring composting are: the large amount of non-compostable material in refuse, need for considerable pre-separation, uncertain market for low-grade product, higher cost than sanitary fill, and incomplete knowledge of the fundamental requirements of the process. The use of raw sewage sludge in composting is very objectionable and would probably be banned in most enlightened countries.

50. Howard, Sir Albert. Experiments with pulverized refuse as a humus-forming agent. The Surveyor 96(2489):333-4, Oct. 6, 1939

Attempts to pulverize and use on land the town refuse for last 20 years have resulted in failure except in Southwark (London) where demand exceeds supply. Humus is made by bacteria and fungi (Indore process) from (1) substances largely composed of cellulose (straw and waste paper) and (2) urine and dung of animals. If insufficient (1) is applied, process is wasteful because organisms get O_2 from sub-stratum (instead of air), decomposition is slower,

50. large quantities of proteins are decomposed the wrong way, and free N is liberated (as in ordinary farm manure heap).

At Bodiam, Sussex, 30 tons of crushed Southwark wastes are used daily. It is composted with hop garden wastes (hop brine, string, hedge and roadside trimmings, old straw, farmyard manure, and other vegetable wastes). Average output is 10,000 tons/year. Gave rapid improvement of soil texture (heavy clay) and splendid crops.

At Marden Park, Surrey, there was a large scale trial of composting pulverized wastes and dung. Crops grown with this humus were superior to those grown with farmyard manure.

Recommends composting in sunny place, facing south and protected from drying and cooling winds and from surface drainage. Layers of town and vegetable wastes (6 in.), then farmyard manure (2 in.), then "good sprinkling of earth." Repeat to height of 4 ft., not more than 5 ft. wide, length not less than 10 ft. Make vertical vents with a crowbar 4 ft. apart. There is a rapid rise to 150° F. which drops after 3-4 weeks when heap is turned; temperature again rises and the heap is turned at end of second month; compost completed in 3 months.

Compost humus should not be evaluated as chemical fertilizer as it overlooks the role of humus which does similar work to artificial manures by providing nutrients indirectly and also feeds plants directly. Living threads of fungus tissue pass from humus in soil into active roots and are digested there. This is mycorrhizal association - the symbiosis of a fungus and the roots of the crop; it is frequently overlooked but important to good crops.

51. Hoyle, Delphine A. and Mattingly, G. E. G. Studies on composts prepared from waste materials. I. Preparation, nitrogen losses and changes in "soluble" nitrogen. J. of the Science of Food & Agr. 5:54-64, Jan. 1954; Abs. Pub. Health Eng'g. Abs. 34:GR7, Nov. 1954 and CA 48:4746h, Apr. 25, 1954

"Changes in the pH and total soluble nitrogen (N) of composts from waste materials have been examined during decomposition for periods up to 2 years. Losses of N, dry matter and organic matter after 14-16 weeks were also determined. The rate of decomposition, based on the level of soluble N in composts from straw and sewage sludge, increased as the initial N content increased from 1.10%

51. to 1.97%; above 1.97% there was no increase in rate of decomposition and losses of N became excessive. Nearly all the soluble N in mature composts was present as NO_3; the pH of mature composts varied approximately inversely as the NO_3 content.

"Supplementary aeration slightly decreased the level of soluble N in mature composts and considerably increased losses of N in 14-16 weeks. Aeration had little effect on losses of dry matter. The soluble N in mature composts from straw and ammonium sulfate was much greater than in composts from straw and sludge prepared with the same initial N content. The optimum conditions for preparing composts from straw and sludge in small cells are discussed and the importance of the level of N, minimal aeration, duration of storage period and influence of soluble N in the starting materials are emphasized."

52. Hubel, John. Milwaukee considers composting garbage. Pub. Wks.:104-106, Oct. 1952

Oakland, California is only city in U. S. using composting. Miami considered the Verdier process. Scarsdale, N. Y. installed a Beccari system about 20 years ago but operation was halted after several years because of nuisance factors which could not be controlled. Milwaukee (W. C. Webb, Asst. Supt., PW Dept.) contacted Frazer Corp. and American Composter Co. (Lansing, Mich.) as well as Dr. Pfeiffer who recommended outdoor composting requiring 10-20 acres for stockpiling. Estimated cost for outdoor composting is $250,000/100 tons/day for installation, cost per ton about $35. Milwaukee is obtaining $40/ton for Milorganite and does not look with favor on getting only $15/ton of dried humus from composting as indicated by California studies. Webb figures 30-day stockpiling of garbage from Milwaukee would require 15 acres; he doubts that there would be no nuisance. Further investigations are to be made by the city.

53. Jansen, J. and Kunst, H. Are pathogenic microorganisms killed in waste dumps where sufficiently high fermentation temperatures occur? Netherland J. Agr. Sci. 1:111-114, 1953

At Wyster, Holland, in cooperation with V.A.M., studies were made on the title subject. Wastes from several large towns are dumped into piles from an elevated railway. Piles are 6 m. high x 8 m. x 475 m. Composting is checked by continuous temperature recording and by watering (300 l/ton). Tests of bacterial kills

53. were made using non-pathogens with resistance corresponding to various pathogens. In summer tests used: *Mycobacterium phlei* (related to tubercle bacilli); *Salmonella abortus equi* (representing paratyphoid bacilli), *Micrococcus aureus*; and *Bacillus subtilis* (spore-former, related to anthrax bacillus). Half of broth cultures were sealed and other half dried and sealed. Of all half were kept at the laboratory and half placed in jars filled with sand in compost piles. Tubes were left in from Sept. 1949 to June 1950. Temperature had exceeded 87° C. but did not reach 98° C. (tested by sealed tubes of substances having different melting points). Tubes were opened and material inoculated into broth and incubated at 37° C. Bacteria grew from all cultures stored at room temperature and grew from *none* of the cultures stored in the compost. Winter experiments tested *Mycobacterium phlei*, *Salmonella typhi-murium*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Erysipelotrix rhusiopathiae* (pathogenic). Mice dead with *E. rhusipathiae* and para-typhoid were also sealed as well as tubes with cysts of *Heterodera rustochiens*. Tubes were buried in compost in Dec. 1951 and recovered in March 1952. Maximum temperature was about 72° C. Bacteria were again recovered from all tubes stored at room temperature and only one tube, containing *B. subtilis* in a dry state, showed growth after inoculation into broth. No growth occurred from tube containing *B. subtilis* in liquid state. No aerobic or anaerobic organisms could be obtained from the decayed mice. Temperatures in the waste dump were uniform except in the upper 20 cm.

Conclusion is that all microorganisms of a divergent character (as tested) perish when stored in compost pile for 3 months.

54. Kaila, Armi (Univ. Helsinki). Effect of nitrogen and phosphorous on humification of straw. *Acta Agralia Fennica* 78(3): 27, 1952 (In English); *Chem. Abs*. 10163i, 1953

"Rate of humification of rye straw (0.39 N, 0.124% P - dry basis) is a function of the amount of added N. N losses were negligible below 0.7% added N. Affect of added P in the process was small."

Humification of straw at various temperatures. Ibid (3): 32, 1952. "Optimum temperature for humification of rye straw is 35°. Rate is a function of temperature over a range of 5 to 65°, with only minor differences in product. Temperature causes major differences in microbial populations during humification."

55. Kaila, Armi (Univ. Helsinki). Nitrification in decomposing organic matter. Acta Agr. Scand. 4:17-32, 1954; CA 48:6063a, May 25, 1954

Straw was moistened with thrice its weight of distilled H_2O carrying from none to multiples of 0.35% of urea N and two samples received 20% by weight of lime. After 16 weeks' incubation the pH of the samples containing 1.05 and 1.4% urea-N had dropped from approximately 8.6 to 6.6 and 4.6 respectively. The pH values at the end of 50 weeks' incubation were lower in all cases except for the 0.7% urea-N plus lime, with the lower values being samples with 1.4 and 2.1% urea-N. The low pH values were correlated with a high content of NO_3-N and lowered NH_4-N values. The highest, 72%, decomposition took place in the 0.7% urea-N sample with the others varying from 53 to 63% and the control 29% after 50 weeks. Results indicate that 0.7% urea-N by weight of straw is the best level to use. Intensive formation of NO_3-N was found in peat samples incubated 9 months at 15-20°. The pH values were closely connected with increases or decreases in NH_4-N content. It was observed that ammonification which precedes the nitrification can rather markedly decrease the acidity.

56. Kenyon, R. J. A new method of garbage disposal. Pub. Wks. 83:75, June 1952

Garbage is digested, with addition of digested sewage sludge, special bacterial culture, and ground rock phosphate. An excess of digested sludge may interfere with composting, less than 15% by weight is desirable. Materials are discharged to a hopper and belt conveyor for picking and metal sorting. It then passes through a high speed grinder and is carried in a closed tube conveyor to the composter. Return conveyor is also closed tube. Composter consists of two concentric silos. Outer one insulates inner one and has a number of screened aeration parts. Inner silo is made of concrete blocks each having six 2-in. aeration holes. Inside are suspended staves with 1-in. perforations. Floor is perforated concrete disc to allow drainage to well beneath. Inoculating bacteria are added to liquid in well and recirculating pump is provided. The liquids are discharged through a perforated pipe grid. Garbage is kept damp but not saturated. Conditions are reported to be aerobic with digestion time of 28 days. Two valuable fertilizers are claimed: humus and highly concentrated liquid. After completion of process, hatches at bottom are removed, permitting use of equipment to unload. Humus is bagged.

56. A city of 10,000 population would require three 25-ton composters, 4 men to operate. A 25-ton composter is 12 ft. diameter x 18 ft. high. A city of 15,000 would produce 200 tons of compost per month plus 3,000 gal. of liquid fertilizer valued at $1.00/gal. Cost of producing compost is given as $7/ton (Ed. note: No mention is made of places of installation; see article by Ralph W. Riker, American Composter Co.).

57. Köhnlein, J. and Vetter, H. Manure decomposition with increasing straw content. Z. Pflanzenernähr Düng. Bodenk. 63: 119-41, 1953; Chem. Abs. 48:5413c, May 10, 1954

The change in wet, dry, and organic matter, weights, and carbon content of cow dung with increasing straw content (2 to 6 kg./day/cow) is given. After 2.5 months' composting, the loss in feces and straw weights was 10, 15, 20, and 25% and 18, 41, 53, and 58% respectively for straw additions of 2, 3, 4, and 5 kg./cow/day. Seepage losses were lowered from 24% of dry weight to 2% by increasing daily straw additions from 2 to 6 kg./cow. Temperatures in composting reached a maximum in 24 days with the 6 kg. straw treatment. In the composted manure, ammonia-N increased from 0.23 to 0.29% as the straw increased from 2 to 5 kg; total N increased from 1.94 to 2.33%; P_2O_5 from 1.21 to 1.25%; K_2O from 1.98 to 2.76; and CaO from 1.95 to 2.36%. The ratio C/N remained unchanged.

58. Kortleven, J. Evaluation of city waste and city-waste compost by chemical analysis. Verslag. Landbouwk. Onderzoek No. 57.7:3-64, 1951 (English summary); Pub. Hlth. Eng'g. Abs. Sept. 1952; Chem. Abs. 46, 1678f

Thirty-five cu. ft. of solid refuse is produced per capita per year, weighing 450-650 lb. (The Netherlands). It contains 60% mineral matter, 20% organic matter, and 20% water. Mineral matter consists of 40% ash and sand, 12% gravel, and 8% C (from ashes). Refuse contains all that is required for humification (lignin, proteins, cellulose, bases, Al and Si). Different ways of treatment for application to agriculture are discussed. Netherlands uses only the VAM process of fermentation. During operation, many nutrients are lost, but losses of P_2O_5 and CaO are moderate. Experiments were made with rasped and sieved composts (Dano and Weststrate), fermented and unfermented. Chemical analysis of VAM composts are given. It was weakly alkaline with ample reserve of P_2O_5, K_2O and CaO. To evaluate composts on the basis of laboratory analysis, much research must be done and new methods developed.

Kriege, P. R. Discussion - A preliminary study of high-rate composting. ASCE Proc. Paper No. 1048:11-12, Aug. 1956

(See 137)

59. Lilien, M. Report on the activities of the Ministry of Health in the field of sanitation in Israel during 1955-56. Tavruah (Assn. for Prom. of San. in Israel) 1 (2 and 3):43-64, Apr. 1957 (The English edition is semi-ann.)

Under "Sanitation Problems in Garbage Collection and Disposal" (pp 58-60) it is stated that collection and disposal of garbage is "one of the most conspicuous problems in urban, and not infrequently rural areas as well." Some packer trucks are now in use (Tel-Aviv). Most cities use the open dump. Jerusalem and Bat Yam have begun sanitary fills "Work has begun on an experimental unit for composting garbage at the Hiriya dump which serves Tel-Aviv, Ramat Gan, Holon, Bnei-Brak and Azur. After a trial period with this unit, a large plant will be erected for composting purposes which will serve the entire area and provide organic fertilizer for agricultural purposes from urban wastes. The engineers and sanitarians of the Ministry of Health are also encouraging this system of garbage utilization as an efficient and sanitary solution to the problem of garbage disposal, and one which fits in well with the agricultural needs of the country. At the present time there are a number of small projects of this kind for composting garbage to organic fertilizer and the Division's workers inspect their operations, though it must be admitted that as yet no adequate solution has been found to prevent fly-breeding at these areas." A revolving sorter with different sized perforations along the drum is used.

60. Lough, R. C. Refuse Composting Developments in New Zealand Pub. Wks. 85(7):77-78, July 1954

Article provides supplementary data for two interim reports by the Committee on Utilization of Organic Wastes. At Auckland a pilot plant treats refuse together with raw sewage sludge or digested undried sludge. Raw sludge gave 10-15° F. rise in temperatures in the compost silo while digested sludge had little effect. Turning the heaps was practiced in order to give both mixing and aeration. Drainage provision was unnecessary but amount of sludge used was limited to provide optimum moisture. Twenty to 30 weeks of composting are required to reach a carbon-nitrogen (C/N) ratio of 15; 18 weeks to reach a ratio of 18. The Auckland plant consists of: receiving hopper,

60. shaker and screens, flail, picking belt, magnetic pulley, crusher, elevator, teaser, silo, maturing heaps, turning machine, maturing heaps, loading machine, and storage or transport. Raw refuse is 60 percent moisture, pH of 4.9, carbon 48.3%, nitrogen 1.74%, C/N ratio 27.9 and weighs 987 lbs./cu. yd. after extraction of unwanted materials. Glass, crockery, etc. are removed by hand on the picking belt and the crusher is a hammermill. The teaser fluffs up the macerated refuse. The silo provides the first stage of composting in a period of two weeks while maturing heaps provide 9 months for additional composting and storage.

At Masterton the refuse is composted unground in high heaps covered with sawdust. It is turned at 6 and 12 weeks by a bulldozer. After the second turning the material is stored under cover to mature fully. It is then screened with large rejects, such as bottles, metal, etc. going to the dump and with smaller lumps being ground and returned.

Although these systems require long compost periods, land is available and it is believed that compost is produced at low cost. Compost from Masterton is sold for about 8 pounds ($22.40) per ton and the demand is always greater than the supply.

61. Ludwig, G. W. Twin Falls, Idaho, Compost Plant. Unpublished report, July 29, 1953

(Data were obtained from Mr. Harry Gorby, former plant manager in Toronto, Canada). The Twin Falls composter operated successfully for over 4 years but burned down. The unit was of wood stave construction of Earp-Thomas design. It was 19'-6" diam. x 22' high and contained 6 tiers. Raw materials were manure, seed house blowing (hulls and chaff from grass seeds), strip coal, and gypsum. Material was ground in a Kemp shredder and windrowed until moisture was 40-50%. It was then placed in the digester which was driven by an electric motor and 12-ft. "bull wheel." The unit operated 16 hours per day and turned out 30 tons of compost in 30 hours. Compost was screened, fortified with rock phosphate, and sold either sacked or in bulk. Tailings were returned to the digester to aid in the inoculation. Earp-Thomas inoculum was used. Compost was sold in Idaho, Oregon, Washington, and parts of California at about $60/ton.

62. Ludwig, G. W. Chicago Stockyards Composting Plant. Unpublished report, July 29, 1953

The composter at Chicago Stockyards is operated by the W. L. Morrison Co. (Mr. Louis Van Prays, Supt.). It composts about 20 tons of manure every three days. Cost of the highly mechanized plant was reported to be over $300,000. Raw manure is windrowed for about 10 days and is then placed into a hopper from which it is discharged to a series of screw conveyors operating at low speed. Material is recirculated about every hour by means of a bucket conveyor discharging to the hopper. Steam is added to the material in hopper, being controlled by temperature and humidity controls. The pH is also controlled. Final compost is dried, bagged, and sold. Two additional 20 ton units are under construction although present operation is not profitable.

63. Ludwig, G. W. T.A. Crane, Ltd., Composter (Toronto, Canada). Unpublished report, July 29, 1953

Composter operates with Earp-Thomas inoculating bacteria but in a specially-designed aerobic decomposition unit. developed by T. A. Crane and Harry Gorby. Plant is located at Seaforth, Ontario, composting garbage and manure. It is approximately 8 ft. wide x 15 ft. high x 30 ft. long, having four 4-ft. wide rubber belts running the length of the unit. Each belt is equipped with a geared turning apparatus and each level has a thermocouple with outside dial thermometer. Ground raw material is dumped on the top belt, travels the length of the belt, and is dropped to the next lower belt. Depth of material on belts is 14 to 20 in. Retention time is 24-30 hours but may be varied by adjustable gear reduction motor. One motor operates the belts and another the turning mechanism.

Initial moisture content is about 60% and raw material is inoculated with Earp-Thomas No. 1 depuration bacteria. It is claimed that manure is composted in 24-30 hours and garbage in 4 days. Plant is scheduled to be moved to Toronto. (Ed. note: The moving belt composter, described above, was later abandoned by Crane who developed a new device. The new unit was tested at Michigan State University and later a 30-ton/day plant was constructed at Kobe, Japan. Each deck consists of two half-drums with horizontal axes which rotate slowly, turning scrapers which move the material vertically and forward towards the outlet with a spiral motion. Material is moved horizontally at about 12 ft. in 4 hours. There may

63. be 3 or more decks with the composting matter passing through succeeding decks in opposite directions. Snell (107) describes the Kobe installation: "The T. A. Crane high-rate digester, with a holding capacity of about 36 tons, or based on a 48-hour digestion period, about 20 tons of raw wet refuse per day. This is a 3-deck horizontal unit with two rows of slowly moving paddles on each deck. The only plant built to date is a 30 ton/day imitation of it constructed in late 1956 by Kobe, Japan .... Construction costs of the Kobe plant are estimated to be $40,000, with operating costs of $2.20 per dry ton of compost end product or about half this price per ton of raw wet refuse. Material is sold to farmers at cost .... about 70% of the total digestion takes place in the digester in the first two days (48 hours) while the remaining 30% takes place during the 7 days in the 2nd stage bin composter, otherwise known as a curing bin.")

64. Maier, Paul P.; Williams, Edward R.; and Mallison, George F. (1). Wiley, John S. (2) Composting Activities of the Communicable Disease Center, Public Health Service: (1) Composting municipal refuse by the aeration bin process, (2) Progress report on high-rate composting. Proc. 12th Industrial Waste Conference, May 13-15, 1957, Purdue Univ. (In Press)

(1) After conducting preliminary studies by composting refuse in windrows, the Phoenix Field Station of CDC developed the aeration bin method. Composting is accomplished, after grinding, in hardware cloth bins 2½' x 6' x 4'. The use of bins, which expose the material to the air on all sides, prolongs aerobic action and requires less frequent turning than windrows. Composting time is about 6 weeks. A plant to handle about 70 tons of refuse per week was designed and has been placed in limited operation at Chandler, Arizona. The plant has the following components: (1) 30' x 40' concrete receiving apron; (2) 30" x 60' double chain, wood flight, primary conveyor; (3) Primary grinder with 100 HP electric motor; (4) 30' belt conveyor; (5) Electro-magnetic separator; (6) Equalizing hopper, 480 cu. ft. capacity; (7) Permanent chute magnet; (8) Nitrogenous-material holding tank (for raw sewage sludge or chicken manure slurry), 200-gal. capacity; (9) Secondary grinder with 75 HP electric motor; (10) 60-cu. ft. aeration bins; (11) Aeration bin conveyor of roller type, 150 ft. long; (12) 5-ton fork lift truck (for transporting and dumping bins).

(2) This is the third progress report of studies of high-rate composting of refuse in laboratory mechanical units

64. at the CDC Technical Development Laboratories at Savannah, Georgia. Additional runs with 15-gal. units indicate that better decomposition occurs when the maximum temperature is reduced (by cooling) to 131-145° F. than in insulated units where maximum temperatures reached 153-162° F. Efficiency was from 12 to 30% improved by cooling, based on volatile solids lost, CO_2 produced, and O_2 utilized. Cooling below 120° F. does not appear desirable. Heat production was measured in a water-jacketed unit and found to be approximately 3,000 Btu/lb. of volatile solids in the initial charge or 10,000 to 12,000 Btu/lb. of volatile solids decomposed during 8- to 10-day composting. This heat might be utilized at a mechanical composting plant. Pre-heating of refuse to 128-132° F. appeared to pasteurize it insofar as the aerobic decomposing organisms were concerned in one run of 8 days. Following this the refuse decomposed normally in a second 8-day-run with no external heat applied (temperature reached 162° F. and averaged 144° F. for 3 days). This indicates it is undesirable to preheat refuse to be composted to about 130° F.; preheating to 100 to 110° F. may be desirable.

65. Mallison, George F. and Hohlich, William F. The composition of residential garbage. Pub. Wks. 87(6):112-3 June 1956

Monthly samples of residential garbage were taken throughout 1954 to determine the composition of E. Lansing, Michigan garbage. The garbage is in paper wrapped packages, most of the other refuse being collected separately. Two to 4 samples of 10 to 20 individual packages each were sampled each month, being sorted into nine groups and weighed. The composition is reported in two tables on a weight percentage basis. Monthly analyses indicated seasonal variations such as: winter-high citrus fruit waste; summer-high green and salad vegetable waste, low starchy food wastes. Moisture was lower than expected in the fruit and vegetable portions and this may be due to evaporation and absorption of excess moisture by the paper used for wrapping garbage by the housewife. Average results were as follows:

Constituent	Moisture Content %	Wet-Basis Composition %	Dry-Basis Composition %
Paper	31.0	19.8	33.2
Meat, fat, fish, and dairy products	24.4	8.3	15.2
Citrus fruit	83.8	11.3	4.4

(continued next page)

65.

Constituent	Moisture Content %	Wet-Basis Composition %	Dry-Basis Composition %
Fruit not citrus	85.6	6.8	2.4
Green and salad vegetables and melons	92.8	20.2	3.5
Coffee grounds and tea leaves	63.8	3.9	3.4
Bread, pastry, sugar and cereals	33.6	8.5	13.7
Corn, beans, potatoes, etc.	81.2	11.4	5.2
Miscellaneous (Est.)	20.0	9.8	19.0

Moisture averaged about 60% and it is estimated that unwrapped garbage would have a moisture content of 70% or more.

66. Martin, James P., and Waksman, Selman A. Synthetic Manure. N.J. Agr. Exp. Sta., Circ. 470:8 pp, Oct. 1952

Manure supplies are so limited in comparison to need that means are needed to increase the supply of manure or some closely related material. "Manure" usually refers to the solid and liquid excreta of livestock, together with the bedding. "Artificial" or "synthetic" manure is composted plant materials or crop residues under conditions that accelerate their decomposition. Synthetic manure has been shown by tests to be as effective in improving soil productivity as the best grades of the natural product. Any kind of plant refuse can be used, including garbage, for making synthetic manure. Plant materials can be used alone or mixed with other materials. No special equipment is required and a great variety of methods may be used to compost the wastes. A widely practiced method is to construct a pile of layered materials 4 to 6 feet high in a 1-ft. deep pit. Plant material is layered in 6" depths, sprinkled with fertilizer, and wetted to saturation. The piles have vertical sides and a dish-shaped top to absorb rain. Piling on wood or concrete base, provided with drainage attachment, reduces leaching losses as the drainage is returned to the pile. One air dry ton of plant waste will yield 2 to 3 tons of wet manure. Piles are turned once or twice; one turning is after 50 days; two turnings are after 30 and 70 days. Chopping of material such as cornstalks in 6" lengths facilitates decomposition. Chicken wire or wood slats prevent blowing of lighter materials. For 1 ton of air dry plant materials, use 60 lb. of ammonium sulfate, 60 lb. of lime, and 30 lb.

66. of superphosphate. Legumes, grass clippings or young rye plants will provide nitrogen in place of the chemical N and half of the limestone. Old manure will help in retaining water and speeding up decomposition but seeding is not necessary. Addition of soil in between layers will yield a potting or planting material for greenhouse and nursery beds. Good synthetic manure can be produced in 3 to 6 months, depending on the type of vegetable matter used. Some materials such as salt hay and sawdust may require a year or two. Much longer periods are required without the chemicals. Good potting soil may be made with 1 part manure to 3 or 4 parts of sandy soil. Composts need extra N, P_2O_5, and lime; they also need air and moisture. Temperatures of 150-175° F. may be reached and, if not kept moist, the manure may become "firefanged." The high temperatures kill germs and weed seeds. Synthetic manure is not new; the Chinese have made it for 40 centuries using stable manure and urine in place of chemicals. Synthetic manure produced from farm and garden wastes will build up the organic matter and humus supply of the soil, maintain high yields, and protect the soil from erosion.

67. Marx, Th. and Sahm, V., Concentrating and composting garbage. *Z. Pflanzenernähr. Dung. Bodenk*. 62:31-8, 1953; *C.A.* 48:4163c, Apr. 10, 1954

West Berlin garbage was composted for periods of 3 to 13 months. Decomposition was accompanied by an initial rise in temperature to 30-40° C., which fell slowly to 30°, and after several weeks sank slowly to equilibrium. Soluble P_2O_5 content was increased after composting; N, except when $Ca(CN)_2$ was added, decreased; K_2O decreased as did CaO while MgO and Mn were relatively unaffected.

68. Mattingly, G.E.G. Changes in the distribution of nitrogen during the composting of straw. *Nature* 169:75-6, Jan. 12, 1952

The author investigated the relationship between soluble and insoluble nitrogen (N) fractions in several composts of straw with sewage sludge after 0, 9, 44, 114, and 471 days. The ratio sludge/straw was 2/1 (dry matter). Initial N was 2.44%, moisture was 65%. Total soluble N increased in 9 days, dropped to a low in 44 days, then increased with time. Ammonia-N did likewise but did not increase much with longer composting periods. Nitrate-N did not appear until 114 days. There was a simultaneous ammonification of soluble N originally present and deamination of part of the original protein. The subsequent increase in soluble N (percentage-wise) in the mature

68. compost was a very slow process which was accompanied by a parallel slow decrease in the fractions of the insoluble N.

69. McCauley, Robert F. Laboratory and operational experiences in composting. Proc. 11th Industrial Waste Conference (Purdue Univ., Engineering Bulletin) Series No. 91 (2):436-453, June 1957 (Conference dates: May 15-17, 1956)

Investigations on composting of garbage at Michigan State University include both practical applied development and basic research accomplished by: 1) operating a 5-ton per day mechanical flow digester (composter), 2) testing a small model digester of improved design, 3) experiments with a large number of 1-ton compost piles, and 4) large-scale windrow composting operation. Basic studies were made largely with laboratory-scale apparatus. Neither the windrow nor the mechanical composting was entirely satisfactory primarily because of odor troubles but their operation served to increase knowledge. Critical factors are aeration, moisture; less critical are pH, seeding and grinding. Compost can be produced that is a very pleasant organic material in about 10 days from such materials as garbage, refuse, and raw sewage sludge. The action is aerobic and thermophilic, self-generated temperatures of 150-160° F. being reached and held for several days. Optimum moisture for garbage was found to be about 56%, and values 10 to 15% higher result in an anaerobic condition. When compost is not stirred or turned and aerated it will become partly or wholly anaerobic. Oxygen is reduced to 4% or less in actively composting garbage within about 4 hours. In windrows, however, at 4- to 10-inch depths the O_2 does not drop to zero and the piles will remain hot for 2-3 weeks without turning. This indicates that O_2 passes from atmosphere into composting material and there is a constant moving of O_2 into the material over the entire period of composting.

Laboratory studies were made on the diffusion rate of O_2 through material such as would be composted, except that bacterial action was stopped by addition of mercuric chloride. Diffusion insufficient to meet the O_2 demand during maximum composting is not sufficient to maintain aerobic conditions in most composting processes. However, it is concluded that "oxygen is probably supplied to composting material in windrow and digester operations by the mechanism of diffusion; carbon dioxide is probably removed from the material by the same mechanism." Although the author points out that diffusion studies were made with low diffusion material (raw garbage), were

69. not done at high temperatures such as are reached during composting, and the highest measured rate of oxygen utilization (O_2 uptake) was used for comparison, Figure 8 shows that maximum O_2 supplied by diffusion rates attained would furnish only 5% or less of the maximum measured demand. (It appears from the last statement that one or more other means of O_2 transfer must account for more of the O_2 movement than diffusion, even if measured diffusion rates were one-fifth or less of rates actually present in composting matter - Ed. note)

70. McCauley, Robert F. (Mich. State U.) Recent developments in the composting of organic wastes. Water & Sew. Wks.:522-27, Nov. 1956

Little is known about basic principles of the composting process by those responsible for treatment of garbage and similar wastes in this country, in spite of current literature and widespread foreign use of composting. Six questions are raised about the process which consulting engineers and municipal officials must have answered before they might select composting as a means of waste treatment. Composting has not been demonstrated to be economically feasible in the U.S.

The laboratory and full-scale experiments at Michigan State University are described. Operation of the Earp-Thomas type digester was summarized by stating that breakdowns were numerous and mechanical troubles made operation difficult. The raw garbage treated (about 2 tons/day) was difficult to convey and the change to screw conveyor solved that problem. Digester operation was not wholly satisfactory: odor nuisances developed and a well-composted material was not always produced. Operations were finally discontinued because of the odors. Windrow composting of ground garbage not put through the digester was conducted with the material put through a shredder upon being turned. These experiments indicated that the windrow process would produce reasonably satisfactory compost in 7-12 days. Attempts to compost some 200 tons of partially decomposed garbage were stopped because of the odor of the starting material and lack of sufficient manpower and machinery. Further equipment development and experimentation should solve the odor problems. With proper operation and the high temperatures produced, flies are not a problem. Composting is economically advantageous over anaerobic methods because the aerobic process goes much faster. In addition the end product of composting is a useful material, pleasant in appearance and odor. High composting temperatures destroy the pathogens.

70. Demonstration of a well-working plant, which must be preceded by equipment and technique development, will be required before composting is more widely used. Whether the process is profitable will await operating experience. The MSU studies have shown that grinding, dewatering and conveying equipment is satisfactory in plant operation. Other equipment development is in process. The use of secret bacteria has never been demonstrated to be of value in composting. Important principles of composting include: adequate aeration to insure aerobic decomposition; desirability of re-cycling material to increase efficiency; moisture control to 50 to 60% in mechanical digester and 65 to 70% in windrows; the attaining of temperatures of 150 to 170° F. Mechanical units are faster than windrows because of continuous stirring and aeration. Basic studies, combined with applied experimentation, have been shown to be valuable at MSU. The basic studies included the effects of temperature, moisture, backseeding, pH, bacterial populations, oxygen requirements, and other variables. A better future for composting is predicted because we now have some of the "know-how" needed.

71. McCool, M.M. Some conditions which affect rate of decomposition of kitchen waste. Contrib. from Boyce Thompson Inst. 12:269-76, 1942

Wastes were collected from various sources - restaurants and household kitchen waste - in N. Y. Paper, glass, cans, rags and other materials were removed. Garbage was chopped with shovels and ground in a Hobart food chopper. Raw garbage ranged: 67-73% moisture; 1.7-3.4% N; 6.4-25.6% ether extractable matter, 2.8-21.2% ash; and pH of 4.4-6.0. Twelve cu. yds. were placed in heaps and covered with boards; half plain, the other half treated with 1/20 (dry) $CaCO_3$ and composting horse manure. Yonkers (restaurant) garbage reached 35° C. and 45° C. in 3 days (treated and untreated) and 51° C. and 67° C. in 5 days. "Process tankage" was the most active material at all periods. NO_3 varied from 7 to 102 ppm. N increased some during the first 4 days, then decreased. Cultures with $CaCO_3$ had slightly less N after 8 days than those untreated or treated with inoculum. At 16 days those with inoculum had less N than the untreated garbage. Inoculum without lime gave greatest increase in ash and "proved to be the most effective treatment for speeding up decomposition." Steapsin enzyme caused a considerable drop in ether soluble matter after 4 and 8 days incubation. The control and inoculum increased in ether soluble matter after 2 days, then decreased, as did

71. that with steapsin. Some slowly rotating cultures and composts were unsuccessful due to the formation of the mass into pellets or balls of various sizes. These formed about 24 hours after start of tests. Suggests in composting that the mass be heated quickly to 40° C. by heated air and by use of inoculum. Stop decomposition before N has declined, then dry, mix and grind the compost. Inoculum is kitchen waste plus horse manure, incubated 4 days at 40° C.

72. McGauhey, P. H. New Methods of refuse disposal. The Sanitarian 15:59-64, Sept.-Oct. 1952

"It is felt that there will come a time when, out of sheer necessity, there will be more and more dependance on composting as a means of disposal of the more than 2 lbs./capita/day of refuse with the resulting composted material being used to replenish land exhausted of organic humus."

73. McGauhey, P. H. and Gotaas, Harold B. Stabilization of municipal refuse by composting. ASCE Proc. Paper No. 302:21 pp, Oct. 1953; Furbank, Arthur W. - Discussion. ASCE Proc. Paper No. 481:9-10, Aug. 1954; McGauhey, P. H. and Gotaas, Harold B. - Discussion. ASCE Proc. Paper No. 595:1-2, Jan. 1955; Paper and Discussions were also published as: ASCE Transactions Paper No. 2767:897-920, 1955

This is a condensed report of the composting studies by the University of California, Sanitary Engineering Research Project (see Bull. 9). "The essentials of aerobic composting to stabilize municipal refuse, developed during more than two years of research into the practice and fundamentals of composting, are presented. Composting processes used throughout the world are briefly reviewed.

"Composting is a natural biological process which proceeds most rapidly under thermophilic aerobic conditions. The principal environmental factors that govern the speed and course of the process are shown to be moisture content, aeration, particle size, and initial carbon-nitrogen ratio. Seeding is shown to be unnecessary, and hydrogen ion concentration proves to be an unimportant factor in composting municipal refuse.

"Important steps in composting refuse - such as segregating, grinding, stacking, turning, and remilling - are discussed, as are operating factors and the judging of the condition of a compost on the basis of observations,

73. course of temperature, and control tests. The time required for stabilizing several types of refuse material by various processes is shown and the merit of finished compost as a fertilizer and soil conditioner is observed. The problems of practical municipal composting are reviewed. It is concluded that composting offers an economical and sound solution to the refuse disposal problems of many communities, at the same time reclaiming organic material of great value to agriculture." - Authors' synopsis (Trans.)

Mr. Furbank indicated that the Indore process, developed by Howard in India, was an aerobic composting process and not anaerobic as indicated by the authors. The authors also reported a serious loss of nitrogen when calcium carbonate is added in composting. Mr. Furbank quotes Albert Howard as stating that the fixation of nitrogen from the atmosphere takes place and under favorable conditions as much as 25% additional free nitrogen may be secured from the atmosphere. Favorable range for fixation occurs at pH 7-8, obtained by addition of calcium carbonate. The Azotobacter (nitrogen fixing) will not tolerate an acidity greater than pH 6.

Messrs. McGauhey and Gotaas indicate that interest in composting municipal wastes has developed rapidly in the U. S. A certain amount of mechanization is needed in the process (i.e. receiving, conveying, shredding, milling, and bagging) but highly mechanized composting units add materially to the cost and probably will not reduce the compost time by a sufficient amount to justify the added expense over the windrow method. It now appears that a windrow composting plant can be built at from 25 to 35% of the cost of an incinerator for plants with a capacity of more than 200 tons/day. A mechanical composter plant might cost the same as an incinerator. A selling price of $5.00/ton, approximately the price of stable manure and steer manure, is visualized.

74. McGauhey, P. H. and Golueke, C. C. Possibilities of composting municipal refuse. Pub. Wks. 84:126-132,160, Oct. 1953

This article reports on the Sanitary Engineering Research Project at University of California studying composting by the windrow method. Two temperature graphs and one table on time of composting by various methods are given. Data are given in other articles and in more detail in SERP Bulletin 9 (See 31 and 73).

75. Michigan State University. Preliminary report on a study of the composting of garbage and other solid organic wastes. *Civil & San. Eng'g. Dept., MSU*, Mimeo. 145 pp, June 1955.

This is the first year progress report on a research project supported in part by the PHS, National Institutes of Health, Project No. RG-4180 and directed by Dr. J. R. Snell. In June, 1953 a modified Earp-Thomas "digester" (composter) was completed and arrangements made to treat the wrapped garbage (separate collection) from the City of E. Lansing. The digester was 23 ft. high and 10 ft. in diameter, having 8 decks with a plow system on each deck and provision for either natural or forced aeration. Garbage was ground, conveyed to a 15-20 ton holding (dewatering) tank (approximately 3-day retention), then conveyed to the digester (approximately 2½-day retention). Laboratory studies were carried out in 22 one-lb. plastic digesters provided with slow stirring, aeration and temperature control by water bath. In addition, some windrow or pile composting studies were made out-of-doors. Constituents of East Lansing garbage were reported (see 65).

Oxidation-reduction potentials indicated a rapid fall of ORP values on garbage stored in a closed container (anaerobic) but fairly constant ORP values in open containers over a 12-hour period. Less time was required to reach anaerobic condition with closed storage on material composted increasingly longer. The nitrogen studies showed, with total N values of 2.1 to 7.6% in raw garbage, a loss of about 50% on composting. Carbohydrate studies (qualitative) indicated that mono- and disaccharides and starches are broken down during composting, but there was little, if any, decomposition of the celluloses or hemicelluloses. Phosphorus transfer (chemical to microbial tissue) studies indicated phosphorus in the form of triple superphosphate was being changed from soluble to insoluble form on composting. Volatile acid studies were conflicting and no conclusions were drawn from them. Many tests were studied in attempt to develop a measurement of degree of decomposition attained by composting but no answer was forthcoming.

Windrow composting studies showed ideal composting requires: 1) daily turning for good aeration, 2) suitable moisture maintained throughout the composting period, 3) material of good structural strength against compaction (to keep aeration voids open), 4) material of relatively small particle size, and 5) good insulation in outside layer to speed up decomposition by thermophilic

75. bacteria. Possible improvements in windrow composting may be attained by keeping maximum temperatures in the 45-65° C. range, and re-seeding if the temperature reaches 65-70° C.

Bacteriological studies indicated that initial action in composting is a carbohydrate breakdown; later protein hydrolysis occurs. At temperatures above 65° C., bacterial counts dropped sharply; the counts correlated well with pH (the initial pH drop in composting may thus be harmful). Bacteriological seeding was advantageous but can be obtained with compost or garden soil (commercial seeding material is not necessary). Oxygen uptake studies showed good correlation between bacterial counts (37° and 52° C. incubation) and oxygen uptake. Based on maximum oxygen uptake, the optimum compost moisture content was found to be 56 to 57% for ground garbage; however, for runs of 130-140 hours in the lucite units, maximum oxygen uptake up to 58 hours was at 68% moisture, beyond 58 hours it occurred at 56% moisture. Similarly, temperature studies showed highest initial O_2 uptake at 35° C. compost temperature but subsequently highest at 45° C. (Note: maximum temperature tested was 45° C.). Maximum O_2 uptake was 1025 c.c O_2/hour for 100 gm. dry weight of garbage, which would amount to 1641 cu. ft. of air/hour for one ton of garbage.

As the moisture content of East Lansing garbage was 65-75%, dewatering studies were made. Vacuum tubes were used to speed up dewatering over the period required by a holding tank (about 3 days, Ed.). Nearly 10 hours were required to dewater garbage to 58.8% by the best perforated tube. Using a probe to sample compost air and analyzing the gases for O_2 and CO_2 showed that O_2 may be nearly depleted in the deeper parts of a windrow in a few hours. Procedures for the various samplings and analyses are given in the appendix.

76. Michigan State University. A study of the composting of garbage and other solid organic wastes. Interim Report No. 1, Mimeo. 41 pp, Mar. 1, 1956

This report is the second report on PHS National Institutes of Health project RG-4180 and covers a 7-month period from June, 1955 to January, 1956. Continued work with windrow composting indicated that, with daily turning and shredding, reasonably well composted material can be obtained in 9-10 days from garbage. Garbage-raw sewage sludge mixtures can be composted in windrows successfully if the sludge is dewatered to 70% moisture.

76. Windrow piles can be maintained in cold weather with compost temperatures above 60° C. when ambient temperatures are -11° to -17° C. Studies were made on three barrel composters provided with screen false bottoms with saturated air introduced either above or below the layer of ground garbage contained in the closed barrel. Barrels held 3.8 cu. ft. of material (14" deep), or about 200 lb. Material was removed and turned or shredded at intervals. Air was supplied at 2 to 4 cu. ft./lb. dry solids/day and outlet air consistently showed 8% or more oxygen at these rates. Higher temperatures and greater drying occurred near the point of air introduction than at greater distances. Five days were required to reach thermophilic temperatures and good composting occurred in 8-10 days. Discontinuing air for a few hours resulted in a sharp drop in temperature. Peak temperature was 75° C. but was always followed by a sudden temperature drop and by fluctuations. At the above air rates and at up to 60° C. compost temperatures, about 10-12 lb. of H_2O was lost per day from a barrel.

Studies on nitrogen, volatile acids, and pH were made. The pH dropped from about 6 to 5 in one day, remained below 7 for about 4 days, then rose to 8 to 9. Volatile acids were highest during the first 3 days (when pH was low) as was NH_3 nitrogen. Organic nitrogen analyses indicated a slow rise for 5 days and then a leveling off (values were about 2% for raw to 2.5 to 2.8 after 8 to 10 days). Because of the reduction in dry weight, however, there were appreciable losses of nitrogen (by weight) during composting. Bulk density of the material remained at about 21 lb./cu. ft. during composting.

The diffusion rates of air through ground garbage were studied in an attempt to determine the means of aeration in windrow or pile composting. The experiments were run in laboratory apparatus using sterilized ground garbage. Diffusion rates were greater at lower moisture content and also greater with decreasing depth of material. Unless forced air is used, diffusion is the means in which O_2 is supplied and CO_2 is removed from composting matter. It is due to a difference in partial pressures of these gases and the atmosphere. Generally, diffusion rates are not adequate to maintain completely aerobic activity throughout the composting material. Forced aeration or frequent turning is needed. Decreasing bulk density or increasing free air space increase diffusion and may be accomplished by shredding.

76. Higher temperature composting than in the initial report was studied; however, the 45° C. temperature previously found best (as measured by O_2 uptake) still proved best. Temperatures of 50 to 70° C. either resulted in incomplete composting (50 to 60° C.) or excessive drying (65 to 70° C.). Bacterial studies indicated marked changes in types of organisms both with time and with temperature in the composting process. Additional studies with phosphorus resulted in no valid conclusions being drawn except that some forms of inorganic phosphorus may be changed to organic phosphorus in the composting process.

76a. Michigan State University. Aerobic decomposition of organic waste material. *Interim Rept. No. 2*, Mimeo. 21 pp, April 1957

This is the third report on a composting research project supported by NIH research grants (Project RG 4180). Temperature control was maintained two ways in 4-gal. (13-lb.) laboratory composters. The first was cooled by thermostatically controlled water coil within the unit. Aeration, but no stirring, was provided. Ground synthetic garbage was used in runs with maximum temperatures of 40, 45, 50, 55, and 60° C. lasting 8 to 11 days. The various solids (total, dry, and volatile) losses were 28 to 54%, best decomposition occurring at 40° C. and decreasing with increasing temperature with one exception. The second unit was cooled by stopping the air supply when the compost temperature rose to a pre-determined level. This stopped microbial respiration, resulting in quick temperature drops, and quick return upon renewing aeration (on-off cycles were only 2 to 3 minutes during the most active decomposition). Partially anaerobic action occurred; no stirring was provided. Nitrogen losses were greater, but more erratic, than with continuous aeration (11.1 to 54.6% losses). Volatile matter losses were good (36 to 46%) but the final material had a putrid odor. Mixing appears important so similar experiments are planned in a rotating drum.

76b. Morel, J. L'usine de transformation de la Chaux-de-Fonds. (The garbage disposal plant at Chaux-de-Fonds). *La Technique Sanitaire et Municipale* 50:171-4, Aug.-Sept. 1955; *P. H. Eng. Abs*. 36(6):GR4, June 1956

This paper describes one of three such installations outside of Denmark and Sweden. The process is called 'Dano'. The other two are near Zurich, Switzerland. The process is one of continuous composting. Essentially, the process consists of bringing in garbage; sorting out metals and glass, composting to a granular material with-

76b. out seeding in organisms or enzymes, screening the final product and using it as a compost. In a Swiss modification for a community of 4,000 persons 4-5 loads can be composted in 4-5 days. Added air in the cylinders increases the heat in the composting material which is considered pasteurized and it can be used immediately."

77. Morrison, A. W., Jr. (Dade County Health Unit, Miami). Personal communication Jan. 2, 1958

The following are in answer to questions about composting and salvage in the Miami, Fla. area:-

1) The "Verdier" refuse disposal plant was never built in Miami. (A modern 900-ton incinerator has been in operation for more than 2 years.)
2) Miami discontinued its rubbish grinding operation several years ago. The grinding equipment was later leased to a private firm.
3) For many years Miami salvaged rags and non-ferrous metals. This practice was discontinued last July when Waste Division employees were placed on a 40-hour work week schedule. City officials feel that the value of salvaged materials barely coverdd the labor costs involved.
4) The firm, Organiculture, Inc., leased rubbish grinding equipment from the City and was provided with City rubbish for its operation. Ground rubbish was piled and composted in open fields. The firm claimed that the resultant material was an excellent soil conditioner. Some of the compost was sold to agricultural interests in South Dade County Organiculture, Inc. ceased operations about 1 year ago.
5) The City of Miami is presently hauling all incinerator ashes to a private metal salvage plant. This plant, constructed by the Proler Steel Corp., 3775 N. W. 46th St., Miami, is an automatic operation which separates all ferrous metals from the ashes. The salvaged metals are shipped to Texas for processing.
(Ed. note: The Organiculture, Inc. was one of the two initial companies merging to form Organic Corporation of America /ORCOA7. See Anon (Nov. 1956), (Dec. 1956), (Sept. 1957). For other Miami items, see 6, 7 and 144.

78. New Zealand, Interdepartmental Committee on Utilisation of Organic Wastes (R. C. Adams-Chmn.). The utilisation of organic wastes in New Zealand. First Interim Report, 5 pp, Aug. 29, 1947; Reprinted from: N. Z. Eng'g. 3(6):563-7, June 1948

78. This Interdepartmental Committee was formed as a result of a petition to Parliament by the New Zealand Branch, British Medical Association. Problems to be considered are: 1) Present soil fertility, 2) Effect on health of plants, animals, and humans of use of artificial fertilizers; 3) Dangers to health of use of composts made from sewage or garbage; 4) Manurial value of composts; 5) Potential amount of compost in New Zealand; 6) Cost and economics of composting; 7) Need for a Royal Commission; 8) Needed research program. Three immediate recommendations were made as a result of preliminary committee investigations: "(a) to encourage one, or more, municipalities to organize 'pilot plants' for composting their organic wastes; (b) to arrange for the processes at the 'pilot plants' to be studied experimentally, and (c) to arrange for the large-scale agricultural and horticultural trial of the composts produced." Specifically, it was suggested that the City of Auckland and the Burrough of Dannevirke be encouraged and supported to the extent of 50% in making pilot plant studies, as these communities have either plans or studies in progress. Other studies recommended were: Process studies by the Department of Scientific and Industrial Research, engineering and cost studies by the Public Works Department, and full-scale field testing of compost by the Department of Agriculture.

The present position was summed up in three points: 1) Farmers and gardeners will buy compost only if it can be shown that it will pay them to do so; 2) Municipalities will only make compost if there is an assured market for it and they are shown exactly how to make it at no extra cost, or preferably with some saving to the taxpayer; 3) The Government should therefore ascertain the value of compost of a given specification, the price at which it could be sold, and the most efficient way to make the compost economically. Two appendices follow: one contains the committee's views on five questions, largely on utilization and value of compost; and one listing 38 references so far studied by committee members.

79. New Zealand, Interdept. Comm. on Utilisation of Organic Wastes (R. C. Adams, Chmn.). The utilisation of organic wastes in New Zealand. Second Interim Report, 42 pp, July 27, 1951; Reprinted from: N. Z. Eng'g. 6(11):396-424, Nov. 1951 and 6 (12):449-460, Dec. 1951

Reports are given on the composting work continued at Auckland and Dannevirke (aided by Government grants), composting experiments and experiences overseas, and

79. other methods of utilization of wastes. Subdivisions are: I. Available wastes; II. Composting; III. Sewage Sludge; IV. Present progress and future investigations; V. Recommendations; App. A. Auckland report on operation of pilot plant; App. B. Auckland refuse data; App. C. Dannevirke report on composting procedure; App. D. Types of N fertilizers sold in N. Z.

I. Twelve cities (8,500 to 145,000) reported refuse figures of 0.41 to 1.00 cu. yd./cap./yr.; 0.11 to 0.62 (long) ton/cap./yr.; density 2 to 5 cu. yd./ton. Masterton reported 60% as compostable, or 0.25 cu. yd./cap./yr., or 0.075 ton/cap./yr. New Zealand wastes are thus much higher in organic matter than British. Total estimated wastes are computed and sketchy reports on farm and industrial wastes are given.

II. Composting wastes should be blended to have about 1.7% N in the raw materials. High and low N-value materials are discussed. Composting matter should not greatly exceed 50% moisture and temperature of 150° F. (170° F. may kill essential bacteria). Any drainage should be returned to conserve nutrients and seeding. Compost should appear rather dry at first as it becomes wetter later. Aerobic is more effective than anaerobic composting. Low moisture or additions of sawdust or paper keeps pores open; compression of heaps should be avoided. Desired end C/N should be about 12 but need not be this low when sawdust is added. Dannevirke added sawdust and sewage sludge but neither helped much; abattoir and fish wastes were helpful. Excessive N losses were reported. Auckland started with good refuse of 1.7% N and C/N of 28. In 10 weeks' composting these values were 2.1% N and C/N of 20, somewhat better values were attained in 20 and 30 weeks (see App. A). Bin or pit composting procedures are discussed for home, small town, and large city use. Composting raw or digested sludge with refuse poses problems in that limited quantities of wet sludge can be absorbed and dewatering of sludge (mostly from septic tanks in N. Z.) is difficult. Various composting processes are described as used throughout the world. Compost quantities, analyses, and values are also discussed.

III. This portion discusses sewage treatment methods, use of sludge as fertilizer, sludge analyses, sewage treatment in N. Z., sludge quantities available and their value, garbage grinding into sewers, health aspects of sludge use, and use of sewage effluents.

79. IV. For the various available wastes, composting presents the best prospect for treatment. Studies show the feasibility of composting of refuse but efforts should be made to reduce costs. Additional studies are needed on composting with added waste materials, such as sewage sludge, straw, and sawdust. Tests lasting 6 years are urgently needed to determine the effect of compost on soil by field growing tests. References listed number 74.

V. Recommendations: (1) Publishing of this report; (2) Conduct of field trial tests under direction of the Horticulture Division, Department of Agriculture; (3) Designs of all future sewage treatment plants in N. Z. should "take full cognizance of the potential value of sludge as a fertilizer"; (4) Continuation of the Committee.

Appendix A - The Auckland pilot plant (10 cu. yd./day) consists of: receiving hopper, shaker and screens, flail, picking belt, magnetic pulley, crusher, elevator, teaser (to loosen balls), composting silo, maturing bins (composting until used or sold). Raw refuse has: C/N of 22.6 to 29.9, pH 4.2-5.5, moisture 58-60%. The silo is a steel bin 13 ft. x 6 ft. x 7 ft. deep with 12-in. diameter half pipes forming the bottom. One foot of material is dropped out by rotatint each pipe section 90° each way from the vertical. Maturing bins are partitioned to hold 18 cu. yd. each. Composting is conducted 2-2½ weeks in the silo and 20 or more weeks in maturing bins. Turning in the bins is planned but has not yet been done. The compost has C/N of 12 to 15 in 20 weeks, the N increasing from 1.4% to 2% in 7 weeks and to a maximum of 2.7% (average 2.3%) in 32 weeks. Temperature in the silo is maximum of 152° F.; in bins, average of 142° F., peak of 148° F. in two weeks, then drops 5.5° F. in each of next 4 weeks. Tile ventilation of bins is being considered and a loader-teaser for turning is on order.

Appendix B gives total refuse and cost data for 3 years at Auckland.

Appendix C - The Dannevirke experimental plant consists of 6 concrete and masonry bins 8 ft. x 8 ft. x 3 ft. deep. The plant has no mechanical equipment and material is unground. Materials are varied but consist primarily of: garbage, sawdust, fish wastes, straw and ashes; secondarily of offal, "skin pieces", grass,

79. "boiling down produce", and sludge solids. Eight bin runs have been made. Composting is usually 6 to 8 months, material being wetted and turned "as required". turning being accomplished only once or twice. Dry weight losses varied from 35.5 to 62.6% and N losses, 46.7 to 76.5% (nitrogen values: initially 1.8 to 2.4%; finally, 1.1 to 1.7%).

Appendix D - This gives N content and cost/ton of inorganic and organic fertilizers sold in N. Z. (no quantities). (See also: 120)

80. New Zealand, Interdept. Comm. on Utilization of Organic Wastes (C. M. Wheeler, Chmn.). The utilization of organic wastes in N. Z. Third Interim Report, 22 pp, 1956

The Third Committee Report consists of: 1) Introduction 2) Experimental Composting in N. Z.; 3) Field Trials; 4) Further Developments in N. Z.; 5) Observations on N. Z. Composting; 6) Developments Overseas; 7) Research Overseas; 8) Equipment and Compost Plants; 9) Economics and Costs; 10) Sewage Sludge; 11) Summary and Conclusions; 12) References (50 listed); App. A. Auckland Compost Plant Report; App. B. Summary and Conclusions (quoted) from U. of Cal., Tech. Bull. No. 9; App. C. Summary and Conclusions (quoted) from Gr. Br. Natl. Resources (Tech.) Comm. "The Use of Town's Wastes in Agriculture."

The only experimental work in N. Z. is now the Auckland studies (see App. A). Government funds are available for a 5- to 6-year study near Auckland to assess horticultural value of composts vs. other organic materials and fertilizers. Trials began in April, 1953 and the plan is described but no conclusions drawn.

Dannevirke studies ended but present compost production is still 80 to 90 tons/year from a population of 4,600. Selling price is 6s 10d/110-lb. bag; 2 pounds 15 s./½-ton lot of 9 bags; 5 pounds/ton lot of 18 bags (long tons). For one year costs were 812 pounds and returns 309 pounds 10 s. Controlled tipping costs would be 800 to 1,000 pounds/yr. Composting works at the following cities are discussed: Masterton (Blake Brothers heap composting); Rotorua (Borough composting from 1951 to 1954 - closed); Hawera (private contractor composting from 1954 to 1956 - closed); Hastings (private contractor composting since 1954); Islington (N. Z. Refrigerat ing Co. composting slaughterhouse waste solids; irrigat ing with liquid wastes); Auckland (Organic Manures, Ltd

80. composts and sells); Dunedin (Organo Compost Co. composting from 1949 to 1954 - closed). N. Z. composting experience indicates: N in compost is not highly available and supplemental N is needed; organic manures are best used on horticultural soils; benefits depend on structure and composition of soil. Overseas composting installations in Great Britain, Holland, Denmark, Australia, U. S. A., Canada, El Salvador, and France are discussed. Research in U. S. A., Canada, Australia, and Britain is also discussed. Three other sections consider: design of composting plants and mechanical equipment; economics and costs of composting; and sewage sludge utilization and composting with refuse.

Conclusions: 1) Composting considerations should be based more on operating plant performances, less on speculation; 2) "There have been claims for special processes, but generally they are characterized by a dearth of information on the type of material used, the end product, nitrogen conservation, and whether a quick process really gives a mature compost"; 3) Composting in protected heaps on ground appears best for small communities. There is little virtue in high-speed processes because of seasonal demand; 4) Auckland results are helpful and may serve as a guide for scaling up to larger plants; 5) Composting may not bring a profit but may reduce refuse disposal costs and makes available a product of use to market and home gardeners; 6) "The fact that after nearly 3 years of controlled growing experiments at Avondale conclusions cannot yet be drawn emphasizes the danger of endeavoring to form conclusions on single season trials"; 7) Increased research overseas is welcome and will put composting on a much more scientific basis than in the past; 8) Technically the composting process is fairly well understood, but a community will still depend on estimated costs and returns. "The Committee, however, would encourage the long-term view that conservation of waste now will benefit the community as a whole."

Appendix A. Auckland raw crushed refuse, after removal of unwanted materials, has the following analyses: Density 36.6 lb./cu. ft. or 882 lb./cu. yd.; Moisture 60%; pH 4.9; Carbon 48.3%; N 1.74%; C/N 27.9. Material from the silo averages: Density 37.1 lb./cu. ft. or 895 lb./cu. yd.; Moisture 59%; pH 5.4; Carbon 48.6%; N 1.79%; C/N 27.1. Although it appears that little composting has occurred in the 2-week silo treatment, 60% of the volume reduction through the plant occurs here and the material has lost its attraction to flies.

80. Matured compost analyses: Maximum average N 2.3%; C/N in 30 weeks 15; C/N in 18 weeks 18; Carbon in 30 weeks 36%; C in 18 weeks 38.5%. There is considerable N loss on a weight basis but the process is considered efficient. Raw sludge additions increased maximum temperatures, digested sludge did not. Coffee grouts (grounds) 1 to 4 with refuse, improved structure, increased N. Providing ventilation with tile and stacks in maturing beds appeared not to help materially. A self-propelled loader with a teaser at the top was very helpful in turning and aerating the bin compost. It is similar to a coal loader, the teaser being a rotating drum with protruding teeth. Two turns are made in maturing beds. Compost is sold for 3 pounds/cu. yd. ex works, costs were 3 pounds 4 s. 6 d./cu. yd.; with depreciation costs would be 4 pounds 10s/cu. yd. If designed for production only, the costs would be less. It may be desirable to discontinue composting when the C/N drops to 18 instead of the desired value of 12, the remaining decomposition occurring in the soil where NH_3 may be used by plants or retained by soil clay.

81. Olds, Jerome. Composting solves city garbage problem. Organic Gardening and Farming, Sept. 1956

Disadvantages of incineration, landfill, and dumping are pointed out. McKeesport, Pa. had an incinerator which "broke down about two years ago" and was hauling its wastes to a sanitary fill. The long truck haul, the cost of covering the garbage with earth and slag, plus the unavailability of a satisfactory dump area caused the search for a different method of disposal. Howard G. Burr, President of Organic Corp. of America (ORCOA), had set up a pilot composting plant at Miami 3 years ago and he contacted McKeesport city officials. In June, 1955 the contract for a composter was consummated between McKeesport and ORCOA. Over $300,000 was spent in financing the plant located at the old incinerator site. Refuse is dumped through a chute to an oscillating stainless steel conveyor. Hand and magnetic separators are used and the refuse then goes through a grinder and shredder, still containing bottles, tin cans, paper, and other trash. The grinders were built by Gruendler Crusher and Pulverizer Co. of St. Louis. Special bacteria are sprayed into the ground refuse and the material is then set up in windrow piles. The heaps are turned by a machine that acts as a snow blower. Compost is finished after 14 to 21 days and is bagged. The plant at McKeesport is designed for 150 tons/8-hour

81. shift and 7-8 men are required for operation. The plant will also handle garbage from the NYC, Penna. and B & O Railroads and from H. J. Heinz Co. Pittsburgh factory.

ORCOA was established on June 28, 1955 from two previous companies: Organiculture, Inc. and Composting, Inc. (pilot plant at Miami, Florida). ORCOA sent questionnaires to about 500 cities asking them about their garbage problems and is promoting other installations. (Ed. note: The McKeesport plant closed permanently the latter part of 1957.)

82. Olds, Jerome. Ten steps to composting success. Org. Gard. & Farm. 4(10):16-24, Oct. 1957

Fall is ideal to compost in order to improve the soil. Use waste such as leaves, garden wastes, weeds, grass clippings, and crop residues. The 10 steps are:-

1) Where to make compost: close to source of supply and use, fenced or landscaped so as not to be an eyesore. Walls can be slatted fence, concrete block wall (holes horizontal), wooden bins.

2) Collecting and assembling materials: Use wastes, including kitchen waste. Although materials may be layered, they will also compost if mixed but in the same proportion as in layering: brush on bottom, 6" layer of green matter, 2" of manure, sprinkling of top soil.

3) Power equipment: Indore process takes 3-6 months. Can compost in as little as 10 days with use of grinder or shredder (a British compost mixer is on the market - see 20.)

4) Without power equipment: Mix well, keep moist, turn often (every 3-4 days), keep heaps small, add earthworms.

5) Improving value of compost: Compost conditions soil, increases water-holding capacity, improves tilth and aeration, and makes nutrients in soil more available to plants. If soil is acid, also add ground limestone when composting. Adding rock phosphate and potash will help, regardless of soil condition. Manure speeds up composting while increasing N content.

6) Watering and turning: Turn at least twice in first 4 days. Have heap quite moist during initial stage.

82. Slope heap to center to soak up water.

7) Mistakes to avoid: Don't make compost heap of one ingredient, i.e. leaves, weeds, or grass clippings. Need to add manure, dried blood, or finished compost to increase N content. Don't let heap dry out or be too soggy. Keep heap small - maximum 5 ft. high, not over 10 to 12 ft. wide at bottom but generally not less than 5 ft. wide. In winter, cover with burlap, canvas, or soil.

8) How to tell when finished: Doesn't have to be crumbly, just broken up and with a rich, dark color. By inspection often one can determine its origin. Allow final decay to take place in the ground. For flower growing it is best to screen out coarser particles.

9) When and how to use compost: When rather fine, a month before planting is all right. Or one can apply half-finished compost in the fall. To apply, turn soil thoroughly and add compost to top 4 inches. In adding to growing crops mix first with soil and apply as a mulch (called "top dressing"). Apply 1-3 inches per year - put on heavily in home gardening. Under trees start 2 ft. from trunk and go to 1 ft. beyond drip line, use 1-2 in. annually. In lawns, first use an aerator to slice up sod, apply fine compost only. Can use a rotary mower to distribute it after application.

10) Sheet composting: This is more efficient but also more work unless a tiller is available. Cut up litter with a rotary mower in place. Spread other material (weeds, leaves, manure), before or after shredding. Add lime, N fertilizers, phosphate, or potash. Till this into the top 3-5 inches of soil. The tiller also gives some shredding action. Special green manure and cover crops can be grown for this purpose.

83. Organic Gardening and Farming. Make Compost in 14 days. Org. Gard. and Farm. Bull. #54: 16 pages, Undated

This appears to be a reprint which includes 6 articles on composting with the following titles: 1) Finished Compost in 14 days; 2) Quick Composting Materials; 3) Rotary Mower Shreds Compost Materials; 4) Faster Composting with Power; 5) Compost Comment; 6) How to Use Compost.

It is claimed that composting at farm or home can now be done in 14 days instead of 3-12 months, and that speed-

83. compost is richer and saves space. Shredding all material prior to composting is the key. Frequent turning - as often as every 3 days - is also important (claim proved at "Organic Experimental Farm"). Three garden-sized shredders were tested: Kemp Model 6, Keston, and W-W model 2-XB. The Kemp and W-W have 2 HP gas motors, the Keston has electric motor. Compost of spoiled hay and chicken litter by Albert Howard method took over 3 weeks to even start, turning was difficult. The various shredders were tested with different materials. The Kemp compost temperature was 130° by the next morning and 140° by afternoon. Composting matter was turned twice in the first week and compost was "ready to use" in 14 days, although not through heating. The Keston with knife blades did the fastest job of shredding but did not shred as finely as Kemp or W-W. All shredders did a good job on mulch materials. Kemp is stalled easily on stringy materials, easy to clear. Keston is very portable and cheap; W-W shreds fresh material well, is quite portable, ejects tough material in separate pile, also stalls on fresh stringy material but easily cleared.

Rules for composting are: 1) Select soft materials like garbage and grass clippings, add high N-materials like manure and spoiled hay; 2) Keep moist; 3) Turn heap often; 4) Use dried blood, bone meal, and manure for N supplements; 5) Search for materials not available (wastes). A number of materials are discussed.

Rotary mowers can be used as shredders. With garden-scale power equipment one can do "sheet" composting, working a green manure into the soil with extra organic material added. A rotary tiller is best to use. Spading under results in very slow decomposition.

Applying compost: If half-finished, apply in October or November so it will complete decomposition by Spring; otherwise apply 1 month before planting by mixing and shredding it in well. Store finished compost under cover over winter; if stored in summer, water it occasionally. Add compost to top 4 inches of soil, sieving through a ½-inch sieve. Do not disturb roots of growing plants but mix compost with soil and apply as a mulch. Apply 1 to 3 inches of compost/year, no danger from burning. Average weight of compost is 1,000 lb./cu. yd. For orchards and trees, use about 1 in. of compost, start 2 ft. from trunk and go to 1 ft. beyond drip line. For potted flowers, screen compost and mix with soil, 1 to 3.

84. Panzer, M. L. and Ludwig, H. F. Should we reconsider composting of organic refuse? Civil Eng. 21:40-41, Feb. 1951

No U. S. city is now composting. Increasing density of population, lack of suitable land areas for fills (also greater hauling distances), more costly incineration to prevent atmospheric pollution, and awareness of reclamation needs all argue for a change to composting. Several composting methods are described, including the Indore, Beccari, Verdier, Dano, Frazer, and Earp-Thomas processes. A brief discussion of the economics of composting is given. Sample figures are also given for basing estimates of revenue from sales of composted material as fertilizer. Authors state that "$15 net per ton of dried humus (derived from approximately 10 cu. yd. of organic refuse) represents a reasonably average figure." Types of communities for which composting seems most practical are also listed.

85. Popel, F. Economic waste disposal problems in the reconstruction of our cities. Proc. Abwasser technischen Verein I:67, 1949; Abs. Sew. Wks. J. 23:822, June, 1951

Composted mixture of digested sewage solids-garbage gives a good-quality, marketable fertilizer-comparable to farm manure.

Primary sludge is treated as follows: first stage digestion, elutriation, second stage digestion, elutriation, and either drying on beds or vacuum filters. Some ashes and dust from refuse are used as absorbents on sludge drying beds.

Garbage [refuse] contains: finely divided mater - 33%; medium-sized refuse (mostly organic) - 27%; large size garbage - 36%; moisture - 19%; scrap materials (iron, other metals, rags, glass, paper) - 4%.

Garbage is sifted to separate the refuse dust. Trash is hand-picked from conveyor belts, the scrap iron being picked up by a magnet (later converted to coagulant). Remaining garbage is thoroughly mixed with dried digested sludge in C:N ratio of 25 to 30. Mixture is composted in piles 1 to 6 m. (3.3 to 19.7 ft.) high and 1 to 3 m. wide. Provision must be made for air access to the centers of the larger piles. Temperatures are kept between 45 and 50° C. by turning piles over periodically for 4 months, when composting may be considered completed. The fertilizer is then sifted in drum sieves to 12-mm size. The residue is returned as seed to the incoming garbage.

86. Public Health Service. Refuse collection and disposal - a bibliography. Public Health Bibliography Series No. 4 Publ. 91, 1941-1950, Mimeo. 90 pp, July, 1951; Publ. 402, 1951-1953 Supplement, Mimeo. 30 pp, July, 1953

Publication 91 contains 1020 references for the 10-year period of 1941-1950 under the following headings:- A. Regulations; B. Finances; C. Storage; D. Collection; E. Street Cleaning; F. Disposal-General; G. Disposal-Incineration; H. Disposal - Sanitary Landfill and Open Dumps; I. Disposal - Garbage grinding; J. Disposal - Composting and Reduction; K. Disposal - Hog Feeding; L. Disposal - Salvage; M. Miscellaneous.

Publication 402 contains 410 references for the period 1951-1953 under similar headings.

87. Public Health Service. Methods for the examination of raw and composted organic wastes. Tech. Dev. Lab.,(P.H.S. Comm. Dis. Ctr.) Chem. Memo. No. 4: mimeo. 24 pp, Dec. 13, 1956

This memorandum describes analytical procedures for seven constituents of raw or composted organic wastes as used by the Technical Development Laboratory (Savannah, Georgia) in the composting research project. The methods are: 1) Moisture: a) Oven Drying Method, and b) Karl Fischer Method;2) Volatile Solids (by ashing in muffle furnace); 3) Ether Extract (Lipids); 4) Crude Fiber (extractions by H_2SO_4 and NaOH, followed by ashing); 5) Sugars: a) Reducing sugars, b) Total sugars; 6) Starch: a) Anthrone-Sulfuric Acid Method, and b) Direct Acid Hydrolysis Method; 7) Organic and Ammoniacal Nitrogen (Kjeldahl-Wilfarth-Gunning Method). All results are reported on a percent dry weight basis except moisture which is on a percent wet (total) weight basis.

88. Public Works Magazine. The Sewerage Manual and Catalogue File, 1957 Edition. Chap. 14. Equipment and Material for Municipal Sanitation; Refuse Collection & Disposal. Pub. Wks. (Spec. Publ.):277-285, 1957

Various components of refuse are defined. Incinerators - Presently only 10% of the incinerator charge is garbage; it used to be 65%. Temperatures of 1400° F. are required to prevent smoke and odor nuisance. Plants must have an area of 105 to 125 sq. ft./ton of daily capacity. Heating value of refuse in NYC is 5,000 to 6,000 Btu/lb. In a 250-ton plant the loading value is 65 lbs./sq. ft.

88. Various makes of incinerators are given. The sanitary landfill and various tractors are discussed. Hog feeding - nearly all States require proper heat treatment of garbage. USPHS, Interstate Quarantine Regulations require cooking at 212° F. for 30 minutes. "An undisputed objection to hog feeding is that feeding lots nearly always give off vile odors, attract flies and rats and are highly unsanitary." Grease extraction plants (garbage reduction) have not been built for many years and are not profitable except when war or other unusual market conditions greatly increase the value of grease. Dead animals may be profitable because of grease, tankage, and hides.

"Composting is being adopted in England and recently advocated in this country." Windrows 5-6 ft. high of ground refuse may be composted, the top covered by 3-4 in. of earth. Temperatures of 140°-180° F. are reached in 2-3 days and the heap is turned after 2-3 weeks. Compost is matured for 8-10 weeks and then screened and used as top dressing for farms or gardens. The "Composter" of American Composting Co. (Lansing, Michigan) is described as a double silo with composted materials and liquid drainage both being sold after 28 days. Wilbro Corp. (Maywood, New Jersey) developed a "garbage digestion system" which involves a mechanical trash separator and washer. "A process of composting with and without inoculants and with temperature control has been developed by Sanitary Disposal Corp." (Lansing, Michigan). "The Organic Corp. of America utilizes a garbage digestion process involving bacteria inoculation to produce a salable product known as 'ORCOA'. The firm will contract with a municipality to operate a city-owned plant or furnish and operate company-owned facilities." Individual and central garbage grinders are discussed. Refuse storage and collection are also presented.

89. Quartly, Eric V. Municipal Composting on a pilot plant scale (a report). City of San Diego, Dept. of Pub. Wks., Sew. Tr. Div., Mimeo. 73 pp, Nov. 1954

San Diego disposes of garbage largely through sales contracts to hog feeders. Vesicular exanthema has been endemic in hogs since 1932 and new regulations require that garbage fed to hogs after Oct. 1, 1954 be cooked. Other methods of garbage disposal that are both sanitary and economical were considered and composting was considered as a possibility. A pilot plant for pile com-

89. posting of garbage was set up by city forces and operated for 6 months. Preliminary laboratory analyses were performed on the segregated garbage in 5 areas of the city, little difference being noted. Raw garbage values for all analyses were: Moisture 69.6%; Nitrogen 2.42%; P_2O_5 1.66%; Volatile solids* 89.8%; Carbon* 49.9%; C/N 20.6. There was very little non-compostable matter in the garbage; in one pile it amounted to only 12 lb. in 6,700 lb. of raw garbage (less than 0.2%).

The pilot plant consisted of a raised truck ramp, funnel-shaped platform with a drainage section, a grinder, wheelbarrow transportation to piles on the ground, initially hand and, later, skip loader turning of the piles. Cost of plant and 6-month operation was $5,558 and operating cost factors were computed as: grinding and piling $2.80/hr.; turning (skip loader) $0.02/ton/time turned; power and gasoline $0.46/hr.; wetting piles $0.05/wetting; amortization - negligible; preparation and clean-up $2.80/pile; fly control and chemicals $1.96/pile. Costs begin with site delivery of the garbage and do not include administration or overhead.

*Volatile solids content was determined but not reported. Carbon content was computed and reported from the formula

$$\% \ C = \frac{\% \text{ volatile solids}}{1.8}$$

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Twelve truck-load piles were composted, loads varying from 5,340 to 8,340 lb. One windrow was made with 5 loads. The following data were presented on each of the 12 piles and the windrow: narrative, temperature-time graph, photograph, initial and final wet weights, initial and final analyses (as above), and costs. One pile was made with unground garbage; 5 other piles were made with ground garbage and no additives; the remaining piles with ground material included 1 with paper added, 2 with straw, 1 with fertilizer, 1 with sewage sludge (digested and filtered), 1 with kelp. Straw and paper were added in small amounts (less than 6% of dry weight) in an attempt to reduce moisture; however, in no case was the initial moisture reduced to less than 59.5%. Final moisture contents varied from 10.1% to 24.8% (average 18.2%) [but because of the soil picked up, these values are probably low - Ed.].

Composting time [taken by Ed. as time for temperature to drop below 40° C. or 104° F.] varied from 34 to 97 days; number of turnings varied from 12 to 28. (Ed. note:

89. These figures indicate that garbage is poor structurally and is too wet to compost aerobically in a reasonable time without additives.) Time required to reach thermophilic temperature (about 48° C.) varied from 4 to 17 days (Ed. note: This was also excessive because of the time needed in most cases for the garbage to drain or dry out to proper moisture content.) In the summary of final analyses (Ed. note: Shown to be "off" considerably due to picking up of soil during composting) results showed the following average values: Moisture 18.2%; Nitrogen 1.48%; P_2O_5 1.42%; Volatile solids 42.2%; Carbon 23.4%; C/N 15.6.

Cost data reported the total cost per ton of *air-dried finished compost* to vary from $1.56 to $20.48 with an average value for the 12 piles of $12.79. (Ed. note: Recalculating these values to cost per ton of *raw garbage* gives from $0.63 to $6.93/ton.) Final weights averaged 33.3% of initial wet weights but most of the loss in weight was loss of water. It was computed for San Diego (population 400,000) with about 50 tons/day of garbage with a composting time of 90 days and a 100% safety factor that the area required for windrow composting would be 25 acres. Production cost (air-dry compost) is estimated at about $10/ton (Ed. note: $3.33/ton of *raw garbage*) with certain savings that might result from more economical operations. (Ed. note: The cost of transporting from grinder to pile by one man with a wheelbarrow, as was done here, makes composting costs excessive. For example: the cost for pile VIII for transporting and piling initially was $4.90 while that for turning the pile 23 times with a skip loader was only $0.91. The use of mechanical equipment to transport from grinder to pile should reduce this cost from $4.90 to about $0.12-$0.20, or the cost of 3 to 5 turnings. The cost estimates given, therefore, appear to be unrealistic.)

The author concludes by recommending that the city: 1) Study the marketability of various types of composted materials; and 2) Study alternate possibilities of garbage disposal, including a) separate anaerobic composting, and b) combined anaerobic garbage-sewage sludge digestion.

90. Quartly, Eric V. San Diego's pilot-plant garbage composter. *Amer. City*:109-111, Oct. 1956

San Diego's garbage is segregated and fed to hogs but outbreaks of vesicular exanthema discourage hog feeding and

90. encourage other methods of disposal. A pilot plant was set up with grinding and composting in piles outdoors. Garbage moisture content was 70%, requiring drainage. Piles were 4.5 ft. high and turned with a Hough front-end loader. Analyses of raw garbage showed little difference from 5 widely separated areas. Average analyses of raw garbage were: - water 72.3%; Nitrogen 2.5%; P_2O_5 1.6%; Carbon 49.9%; and C/N ratio 20.2. Twelve compost piles were set up each containing 5,340 to 8,340 lbs. and one windrow consisting of 5 loads. Each was an experiment and is discussed briefly. Some additives were used either to improve moisture and aeration (paper, straw, and kelp) or to add nutrients (sewage sludge). Straw was the most effective additive. Compost periods were 20 to 94 days and number of turnings were 12 to 27. Final analyses were: Moisture 10.1 - 24.8%; N 1.0 - 2.1%; P_2O_5 0.7 - 2.3%; Carbon 12.8 - 38.6%; C/N 11.2 - 21.7. Final weight was 22 to 46.5% of initial wet weights. Costs per ton of finished compost varied from $1.56 to $20.48 but these costs could be reduced in a larger installation. Recommendations made were: 1) Determine the marketability; 2) Investigate alternate methods, as: a) Separate anaerobic composting, b) Combined anaerobic garbage-sludge digestion.

91. Ransome, F. H. Straw-sludge manure. The Surveyor 103: 525, 1944; Abs. Sew. Wks. Jour. 17:395, Mar. 1945

Straw is soaked and nitrogenous matter added. Underdrained area with tile every 2 ft. 6 in heap is built 9 ft. wide, 6 ft. high and of suitable length. With dried sludge, an 18 in. layer of straw is covered with 2 in. of dried sludge, then repeated. Temperature should rise to 160° F. in 5 days, giving well-rotted straw in 3 months. With liquid sludge, layers were built up with 18 in. of straw then settled primary sludge of about 6% solids, applying 1,200 Imp. gal. (1,500 U. S. gal.) per ton of straw. Build heap rapidly. The wet sludge may be sprayed on with a hose. The resulting product resembles well-rotted farmyard manure with a somewhat higher N content but lower K_2O content.

92. Read, C. T. Notes on the simultaneous disposal of sewage sludge and house refuse by composting to produce agricultural fertilizers. The Inst. of Sewage Purif. Jour. and Proc.:285, 1941; Abs. Sew. Wks. Jour. 15:578-9, May, 1943

A plant for disposal of sewage sludge and house refuse has been operating at Maidenhead, England for about 7

92. years. The process is based on the principle that sewage sludge acts as a powerful ferment on pulverized house refuse. The operation is as follows: (1) separation of ash cinders, etc. by screening, (2) salvage of saleable materials such as paper, textiles, glass, metal and bones by hand picking, (3) pulverizing of the residue, (4) magnetic separation of tins, (5) deposit of pulverized matter into beds about 3 ft. deep, (6) impregnation of bed with crude sewage sludge, (7) frequent turnings of impregnated refuse under cover, (8) maturing in dumps in the open.

In answer to questions the following points were elucidated: (1) the N content of compost may be as high as 5 times that found in farmyard manure, (2) the temperature reached during fermentation is high enough to destroy weed seed, (3) moisture content is not constant since, during the latter part of the process, the material is stored in the open, (4) whole output of sludge and refuse is used, (5) composting bags should be under cover, (6) the composting is done within 200 yards of nearest habitation, (7) the refuse collected is 110 tons per week and the compost produced about 45 T/week.

93. Reid, Geo. W. New horizons in biological treatment of domestic wastes. Pub. Wks. 86(7):89-90, July 1955

Sewage and refuse disposal, rather than recovery, has been emphasized. Refuse and garbage disposal has advanced from dumping and hog feeding to incineration and landfill. Refuse is handled separately from sewage and other liquid wastes. The author deplores waste from sewage disposal (The Oklahoma City Sewage plant discharges 8,300 lbs. N, 2,500 lbs. P/day). The growth of algae, conserved as food, desirable. Algae could use CO_2 from the sludge gas. A pilot plant at the University of Oklahoma grows algae in a revolving drum, harvesting by a moving knife-edge; aeration is with sewage gas. Aerobic compost appears most promising for refuse treatment. Industries (cotton in Texas, peanuts in Georgia) use composting to recover wastes at a profit. Incorporate trash and sewage sludge - but the author does not advocate use of raw sludge. Digested sludge lowers the C/N and controls H_2O.

94. Rich, L. G. A critical evaluation of municipal composting. Pub. Wks. 86:122-134, Apr. 1955

94. The author is one of a committee asked to study a composting proposal by an un-named Virginia city. European cities first used composting soon after World War I. Composting is either anaerobic, requiring months, or aerobic, requiring a few days or weeks. Steps in municipal composting are (a) removal of non-compostables, (b) grinding, (c) placing for composting, (d) turning or aerating, (e) regrinding and bagging or bulk storage. /Ed. note: drying not mentioned./ The value of compost is difficult to estimate. Oakland sold to Ferry-Morse Seed Co. for $4 per cwt. Frazer at Mt. Wolf, Pa. sold for $6.00 per 80 lb. bag. Farm manures generally bring $4 per cwt. and compost may do the same; probably not over $20/ton in bulk or $30/ton marketed through a sales organization in 100-lb. bags. Chemical fertilizers bring 15-20¢/lb. of plant food material (DW); cottonseed meal (7-2.5-1.5) brings 40¢; milorganite (6-2-0) brings 50¢; cow manure and digested sludge (2-1-1) bring 100¢ (based on $4 per bag); compost (1-1-1) would bring 135¢ on that basis. Only 100,000 tons of sewage sludge is sold per annum and nearly half of it is sold in California. The cost of composting has been variously estimated:- Oakland costs were $35/ton but tentative plans are to reduce this to $21; University of California estimate is $15/ton or less; Growth, Inc. (designing plant for Kansas City) estimated cost at $12/ton in a digester; Snell (Michigan State) estimates cost at $10/ton. Status of composting in U. S.:- Compost Corp. of America, Oakland, Cal. - Operated (open-air) 1950-52. Has not been resumed; Frazer, Mt. Wolf, Pa. - Unsuccessful in digester. Got only 3-3½ tons/week instead of designed 10 tons/day. Faulty design and mechanical difficulties; Frazer, Bay Shore, L. I. - Same as Mt. Wolf; Frazer, Chicago Stockyards - Composting manure in digester was abandoned and replaced by a combination open-air and digester process; Organiculture, Inc., Miami, Fla. - Digester plant has operated 1 year and is still in experimental stage. Only a small percentage of tree and brush trimmings collected by the city are used by the company, no garbage; Growth, Inc., New York City - Pilot plant on Staten Island reported as a success. Growth, Inc. plans to enter into contracts with cities to build composting plants, using bond issues to gain initial capital. All profits to go to an educational fund, reportedly.

Proposed operations:- Kansas City, Mo. - Considered a Growth, Inc. plan for $200,000 unit but is still feeding garbage to hogs; Hagerstown, Md. - Signed contract in

94. 1952 with Frazer but in April 1953 decided to cancel contract after Bay Shore plant difficulties; Milwaukee, Wis. - Investigated outdoor composting and estimated 100 ton/day (refuse) plant would cost $250,000. Decided not economically feasible. (Although Milorganite sells for $85/ton (100 lb. bags) the city realizes only $31.89 and compost costs $38.69/ton to produce.) Research at University of California and Michigan State University are mentioned.

95. Riker, Ralph W. American Composter - Organic Garbage Disposal Systems - "turns garbage into gold." Leaflet - Ralph W. Riker & Co., Lansing, Mich., 1 p, Undated

American composters are double-walled silos. The inner silo is aerated internally and externally. The outer silo is for weather and sanitary protection, freezing, flies, vermin, and rodents. Liquids seeping from the garbage are pumped and sprayed back into the garbage. Time is 28 days. Capacities are 25 to 100 tons "at a time." Auxiliary equipment consists of grinding equipment, sealed tubular conveyors, and high-speed unloading conveyors. Sludge and garbage may be composted together. "The American Composter Organic Garbage Disposal System is a clean, odorless, sanitary, mechanical means to safely dispose of all organic waste of the town or city for a profit."

(Ed. note: The only plant installed to our knowledge treated poultry wastes at Wyandotte, Michigan. Originally it was a single perforated silo but the odors were so bad the second (outer) silo was installed around it. The plant was apparently unsuccessful as Riker has now turned to a different type of unit; see 96).

96. Riker, Ralph W. Garbage can produce revenue. Pub. Wks. 87(8):107, Aug. 1956

The Riker composting method by Johnson & Anderson of Pontiac, Michigan, for the Sanitary Disposal Corp. of East Lansing, Michigan, may be the answer to revenue from waste disposal. The system is the result of four years of research with city garbage; digested, and raw sludge, and many other organic wastes. A model plant was constructed at Williamston, Michigan (population 2,500) which provides capacity for a population of 5,000. It has been under experimental operation. Composting chambers are of steel construction in two units of 8 chambers, each of 4 tons capacity (64 tons of raw

96. material). Each chamber is equipped for induction of moisture and air and for removal of the excess gases from composting materials. The plant is designed to treat sewage solids and garbage. Raw sewage sludge is pumped to the plant where it is dewatered by a Komline-Sanderson Coilfilter, then fed into a mixer with garbage which has been ground through a Jeffrey hammer mill. Bacteria are added in the mixer. A Hapman conveyor elevates the material to the top composting chambers. The same conveyor also removes the finished compost to the storage bin, where it is reground for bagging. Finished compost has 40-50% moisture. Costs are reported to be low and, when the value of the compost is considered, an income should amortize the cost of the construction in a short time. Designs of 25 to 100 tons per day capacity plants are being prepared for larger city operations. The most satisfactory temperature range for the composting was found to be 110-130° F. Average N-P-K analysis was reported to be 2-2-2.

97. Rodale, Robert. Composting - An expanding frontier for industrial waste treatment. Industrial Wastes, 2(4):92-95, July-Aug. 1957

Development of a composting process for the treatment of industrial and municipal wastes has been held back in the past by: (1) Lack of sound engineering information of the chemistry or materials-handling aspects of composting, and (2) Mental reservations about the process by management people.

Great progress has been made in the last 5 years by academic investigation. Also compost fertilizer has increased in use (USDA figures) from 416 tons in 1952 to 12,095 tons in 1955. "Natural" organic fertilizers of all types increased from 293,183 tons in 1950 to 461,000 tons in 1955. Compost could be sold in bulk to contract purchasers at $15-20/ton. Composting prepares organic material for application to the soil as fertilizer. It will increase the value of certain organics (sawdust, tanbark, cotton gin wastes, wood chips, cocoa bean hulls, buckwheat hulls, sugar cane wastes, peanut shells, etc.). These materials are stable in the raw state but not sufficiently valuable to be sold as fertilizer. When composted, especially with other materials richer in N, it will become valuable and salable. Composting is superior to drying or dehydrating because it increases the proportion of N and other major nutrients in the finished product. Analysis given from the University of

97. California bulletin show the following increases: N - 1.66 to 2.45%; P - 0.13 to 0.27%; K - 0.80 to 1.65%; C/N ratio - 24.9 to 14.1 (Table 6).

Shredding before composting has the advantages of: (1) shortening compost cycle to 10 days (heap method), (2) making turning of piles easier, (3) reducing space required. University of California reported composting in piles in 14 to 21 days. High temperatures (150° F.) "cooked" the garbage and killed bacteria. Has no smells or flies. Heap method may be done indoors in cold climates, such as the Organic Corp. of America (ORCOA) plant at McKeesport, Pa. The plant handles garbage and refuse. Composting in digesters may be more practical because of faster action. The Michigan State University plant is described. The most successful digesters are at Chicago Stock Yards Compost Co. where 1/3 of the 50,000 tons of manure produced per year is composted. The plant cost $1 million. Manure with a high straw content is difficult to compost. Digesters are square each holding 20 tons, heated air is injected to them, and the manure is composted in 24 hours. Plant operates continuously. Compost is sold under the name "Fertilife" A picture and drawing of USY plant are given. Manure is fed and recirculated with a screw conveyor, every 1½ to 2 hours. It is "disintegrated" with a "fan" as it is fed into the top of the digester. The bottom appears to be made up of cylinders but they may be screws also. Plants composting tanbark (Elkland Leather Co., Elkland, Pa.) and cotton gin waste (Tagus Ranch in California) are mentioned.

98. Rupp, V. R. Composting paunch manure. Proc. of the Sixth Industrial Waste Conference, Purdue Univ. Eng'g. Bull. Series No. 76(6):363-366, Nov. 1951 (Conf. dates: Feb. 21-23, 1951)

Paunch and pen manure from cattle are composted with loam and ground limestone at Kingan & Co., Indianapolis. A trench is dug 2 ft. deep x 5 ft. wide and of necessary length. Place 6 in. layer of drained paunch manure, 2 in. layer of pen manure, 1/8 in. layer of loam and ground limestone (half and half). Repeat layering to depth of 5 ft., tapering slightly above ground. Three-inch holes made at 5 ft. intervals for ventilation. A two-inch layer of loam is placed on top and the middle is slightly depressed to hold water. The heap is watered if necessary. The temperature rises to about 150° F. in a few days and then falls. It rises again

98. after turning which is done at about 3 weeks. The temperature may rise to a higher point after turning. In about 5 weeks more, the temperature will drop to about that of the environment and the heap is turned again. A slight rise in temperature may again occur. Temperature is a good indicator of the activity of the compost pile. Finished compost is friable, black in color, has a faint earthy odor. Weed seeds are destroyed and compost can be used on lawns or gardens. Winter composting is not very successful - digestion is slower, more frequent turnings are required, and final compost contained some weed seeds. Selling price of compost to a limited local market results in a small profit, but sale to larger commercial users is limited by the present high labor costs.

City of San Diego (See 89, 90).

99. Scheffer, F., O. v. Plotho, E. Welte. Studies on the formation of humus substances by actinomyces. Landw. Forschung. 1:82-92, 1950; Chem. Abs. 44:5049d

"Eight strains, isolated from calcarious soil (pH-KCl 7.2), formed dark brown substances by a process of autolysis and described as a process of autoxidation with following condensation or polymerization. Yield depended on C and N source and was highest by application of glycocoll and glutamic acid. By spectographic measurements of absorption with ultraviolet light, color-substances formed by actinomyces were as true humic acid and showed a similar quinone structure as gray humic acid. They originate from products of metabolism."

100. Schweining, Henry L. Industrial wastes effects at the South San Francisco, California, sewage treatment plant. Sew. and Ind. Wastes 29(12):1377-9, Dec. 1957

(Ed. Note: only the portion relating to digested sludge-paunch manure treatment is abstracted.)

Swift & Co. slaughter house discharges 700,000 gpd of presettled wastes to the sewer system. The pre-settling basin removes some of the grease and settleable solids, the latter being largely paunch manure. The settled matter is screened by two vibrating liquid type screens which are 4 ft. x 8 ft. in size and use 20- by 30-mesh screening. The screened paunch manure is delivered to the sewage treatment plant by truck and dumped on the

100. sludge drying beds. It is spread to about 6 in. in depth and used as a filter base upon which the digested sludge is spread. After spreading paunch manure, the beds are flooded with sludge containing 10 to 12% solids, then allowed to dry from 14 to 30 days. At about 60% moisture content the sludge and filter base are roto-tilled by the Geraghty process. The flooding and tilling process is repeated 3 to 4 times, then the tilled sludge is harvested.

101. Scott, James C. Health aspects of composting with night soil. World Hlth. Org., Expert Committee on Environmental Sanitation, 3rd Session, Geneva, mimeo. 8 pp, July 27-31, 1953

The main health problem with nightsoil is that of the fecal-borne diseases, including bacterial, protozoan, helminthic and viral diseases. Nightsoil may be disposed of: 1) in bored-hole latrines; 2) by processing in a sewage treatment plant; 3) by composting. The latter method is of value to agriculture and hence to the nutrition of man and his domestic animals. Nightsoil consists of human feces and urine together and is collected in a pail latrine. Scavengers then transport the nightsoil to the treatment plant area. Composting is done in stacks of 1,500 to 3,000 lb. of material each. Other materials, such as vegetable matter, manures etc. are used with nightsoil. The following mixtures are reported to be satisfactory and to conserve 80% of the nitrogen: 1) Feces or nightsoil 20%, soil 5%, vegetable matter 75%. This results in C/N of about 35; 2) Feces or nightsoil 10%, horse manure 15%, cow manure 25%, vegetable matter 45%, soil 5%. This gives a C/N of about 30; 3) Feces or nightsoil 40%, horse manure 7%, cow manure 7%, vegetable matter 40%, soil 6%. This gives a C/N of about 24.

Composting should result in temperatures of 60° C. or greater. Once this temperature is reached and held for 1½ days, the pile is turned and the composting repeated at 60° C. for 1½ days before a second turn is made. Aerobic composting can be completed in 3 weeks. Composting is best done in shallow pits provided with drainage collection and a roof.

102. Seabrook, C. S. The composting of municipal garbage and sewage sludge - final report and recommendations. City of Tacoma. mimeo. 9 pp, June 1, 1954

102. Only a summary of experimental composting conducted Jan.-July, 1953 is presented; this report is primarily on a market study. Composting was attempted as cheaply as possible using: no preliminary segregation or grinding, composting in open piles on gravel, and final screening. Conclusions of the composting work, using refuse and sewage sludge, were: 1) Decomposing action started spontaneously without inoculums; addition of composted material or sewage sludge to refuse enabled faster starts; 2) Paper was decomposed though slower than vegetable wastes; 3) Winter rains maintained 40-60% moisture; dry summers required addition of water; 4) Turning piles twice weekly with a bulldozer was satisfactory; 5) Temperatures reached 150° F. then fell to completion of the process; 6) One test for pathogen survival was negative; 7) The compost was quite granular, easy to screen out foreign matter; 8) Time required for composting was 6 to 8 weeks, may be shortened by returning large volumes of finished compost. 9) Quantity of material required to be buried was one-eighth of original volume of refuse; 10) Quantity estimates for the City are: 13,000 loads of refuse and 2,500 cu. yd. of sludge will produce 28,500 cu. yd. of compost per year (population and size of loads were not given). 11) Estimated windrow composting costs are: Plant $109,000; annual operation and maintenance $94,700. 12) Compost can be produced at $2.50 per cu. yd. (ed. note: this is apparently considering only operation and maintenance cost plus a yearly saving in operation of the present refuse dump of $20,000.)

The market study consisted of producing compost in limited amount and arranging for the Orthopedic Guild of Tacoma to market the material. Compost was sold in bulk or in 50-lb. polyethylene-lined bags. Bags retailed at $1.50, half going to the Guild. Bulk material was priced at $5.00/cu. yd. (Ed. note - about $10/ton) but there was not enough material to make many sales. The compost sold well and many repeat orders came in with a minimum of advertising. It was concluded that, with full production, there will be a small package market ($1.50/50 lb. bag), a considerable landscaping market (at $5.00/cu. yd.), but the farmer will have to absorb most of the material, possibly at as low a price as $1.00/cu. yd.

Final recommendations to the City were: 1) Composting of municipal garbage* and sewage sludge on a permanent basis be undertaken rapidly; 2) The City should make the compost and control it; 3) A plant costing $80,000 con-

102. struction and equipment and an operating cost of $65,000/year is recommended. (This includes only one, instead of two or three, bulldozer and will not process all of the wastes of the city.) 4) Arrangements should be made to test the compost over a period of years on crops.

*refuse (Ed. note)

103. Shrikhande, J. G. The biological decomposition of green manures. I Carbon-nitrogen transformations during decomposition. Indian J. Agr. Sci. 15:95-103, 1945; Chem. Abs. 42: 6483d, 1948

"A C:N ratio of about 12:1 was found for most of the green manures investigated. The C:N ratios of residues after water extraction were the same as those of the original materials, but differed after hydrogen peroxide extraction. All the green manures except tea leaf finished with a negative N factor with ready ammonification of the plant protein. Tea leaf failed to produce NH_3; this suggests that its N loss is perhaps due to elementary N. C:N ratios of all the composts from green manures are lower than those of the parent materials. It is therefore considered inadvisable to compost such green manures because of the large loss of N occurring during the process. Peroxide extraction produced a greater loss of C and N from green manures and composts than did water. The C:N ratios of residues after extraction of composts with H_2O_2 were lower than for the composts themselves. Nitrification tests showed a relationship between total nitrates formed and initial total N content of plant residues, but no strict relationship was found between nitrification and water-soluble nitrogen."

104. Snell, John R. The future of composting. Proc. Local Govt. Conf. on Refuse Disposal Methods. Univ. of Pittsburgh: 74-82, 98-99, April 22-23, 1954

Composting of organic wastes is compared to automobiles in 1900 and present high-rate composters to the Model T. Composting is (1) an efficient and sanitary method of treatment for most organic wastes, (2) profitable, (3) returns valuable wastes to organically depleted land. High-rate composting converts in 2-3 days raw organic wastes to a stable organic fertilizer analyzing about 3:2:1 (N:P:K). Temperatures of 150-165° F. are caused

104. by thermophilic organisms, killing disease-producers, and driving out moisture. Finished compost can be produced for \$10/ton (20% H_2O) or \$2.50/ton on the basis of raw garbage (75% H_2O). It should sell for \$20/ton. If used in the 12,500 cities of U. S. (over 500 population) having a total population of 100 million, 36 million wet tons of wastes (at 2 lbs./cap./day) or 9 million dry tons would be treated. The compost, bringing \$400/ton for N, \$200 for phosphorous, \$100 for potash (and allowing for value of organic) would result in in \$322,200,000 yearly. Compost makes N,P,K slowly available, helps hold H_2O in soil, produces CO_2 which is desirable, improves soil workability and aeration, and contains some valuable trace elements. The author points out weaknesses of present methods stating that Earp-Thomas method is probably the best process today. Studies at Michigan State College are described, working with 22 one-lb. lab units, large scale digester, and composting on the ground using garbage. Work on composting garbage and sewage sludge is planned but improved sludge dewatering will be undertaken. Schematic drawings and graphs are presented. Graphs show moisture, ash, pH, temperature, OC, O_2 uptake.

Discussion. Mr. Foster asked how Dr. Snell arrived at cost data when the composting process is still in the experimental stage. Dr. Snell stated that he believed a conservative production cost of \$10/ton for the end product was reasonable; not with the Model T plant but by computing the materials handling costs. As for the sale price, it is selling out of Chicago at \$5/100 lbs. or \$100/ton, being wholesaled for half of this, bagged. This is a better product than refuse compost. Sold in bulk, it would bring about \$20/ton. Mr. Weaver related statements made to him by Mr. Dawes of England in which the farmers got together and first reduced the price of compost, later demanded it free, resulting in shutting down the composting operations. Mr. Shipstead indicated that Milwaukee has to maintain a national sales organization in order to maintain their sales (of Milorganite, Ed.). The Dutch have been able to maintain their V.A.M. composting market but, considering the whole cost of disposal, do not make a profit without considering the cost of disposal by other methods. Dr. Snell indicated that in California it was shown that the mere presence of organic matter in the soil resulted in the same crop with 40% less commercial fertilizer.

105. Snell, John R. High-rate composting - A new idea in Municipal garbage disposal. Cons. Engr. 4:49-53, Aug. 1954

> High-rate composting can convert garbage or sewage solids into stable organic fertilizer in 2-3 days. The temperatures of 150-165° F. produced will kill all pathogens. The process is enclosed and there are no bad odors. Average compost contains 3% N, 2% P, 1% K_2O. High-rate composting is claimed to have these advantages: (1) Efficient, sanitary method for most organic wastes; (2) Profitable; (3) Returns valuable wastes to organically depleted lands. Compost can be produced for $10/ton of compost at 20% moisture, or $2.50/ton of wet, raw garbage at 75% H_2O. It might sell for $20/ton, or a profit of $2.50/ton of the wet garbage. Various methods of composting are discussed briefly and the rest of the article describes Michigan State College work on composting-including 22 one-pound lucite digesters and the larger modified Earp-Thomas digester. The latter, serving East Lansing, is 10 ft. diameter x 23 ft. high with 8 decks. A bottleneck in the full-scale plant has been the elevating bucket conveyor because the wet raw garbage sticks to it. Retention in the digester is 2-4 days and seeding with end product is practiced. The aerobic composting showed no nitrogen loss. A new prototype model (the Crane type - Ed.) is ready for testing which might be constructed in sizes up to 100 tons/day.

106. Snell, John R. Some engineering aspects of high-rate composting. Amer. Soc. Civil Engr. Proc. Paper 1178:36 pp, Feb. 1957; Rogus, Casimer A. Discussion. ASCE Proc. Paper 1349:3-4, Aug. 1957 (Jour. San. Eng. Div., 83 (SA4)

> High-rate composting is compared to conventional anaerobic sludge digestion and activated sludge processes. In both comparisons, composting is shown to have economic advantages. The experiments on composting conducted at Michigan State University under (1) basic laboratory research, (2) continuous flow pilot plant, and (3) windrow composting are described. It is claimed that organic wastes may be stabilized in 2-4 days if these essential criteria are followed: a) Material should have a C:N ratio of 50:1 or less, no serious deficiency of essential foods, and be in a pH range of 5.5-8.0; b) Material should be finely ground; c) moisture should be controlled throughout at 50-60%; d) Seed compost (2-10%) should be re-cycled; e) constant or intermittent (every 5-10 min.) stirring should be provided; f) maintain at

106. least 50% O_2 in compost air; g) Control temperature (optimum 45° C.); h) Prevent pH from going too high to permit nitrogen loss; i) Provide continuous flow process in 3 or 4 stages, including recycling of seed and thorough mixing for each stage.

Final compost, while not completely decomposed, will not over-heat, lose appreciable nitrogen, or become offensive. Suggested design criteria are discussed under the following headings: 1) Materials which may be composted; 2) Receiving; 3) Sorting and salvage; 4) Grinding; 5) Dewatering of separated garbage; 6) Pre-storage; 7) Mechanical digestion; 8) Curing, drying, and storage bins; 9) Conveying; 10) Final screening and sacking. Mechanical digesters (aerobic, thermophilic decomposition in an enclosed mechanical unit) have the following essential features: a) Simplicity, large capacity, ruggedness, freedom from clogging; b) Flexibility, especially in flow-through time and air flow; c) Slow continuous or intermittent mixing and aeration with a minimum of power and equipment; d) Feed-back device for seeding in three stages; e) Controls for air, moisture, and temperature in each of the three stages. Post-digestion or curing bins are suggested with upward aeration for additional decomposition for 2 days, then downward aeration for drying for 4 days.

Mr. Rogus indicated that the long-range application of refuse composting appears promising but construction of full scale (100 ton per day or better) plants at present appears premature. Reasons are: 1) Processing of unsegregated municipal refuse poses still unsolved problems of design and operation and introduces high cost elements, and large-scale segregation at the source, through multiple collections, is not practical or economical; 2) The economic advantages of refuse disposal by composting, as compared with other methods, must stand on its own merits without tie-ins to the questionable revenues from salvage or compost sales; 3) Development of practical composting cannot be left to private industry and rich capital; government subsidies are needed to secure continuity and objectivity, even though at present there are problems of agricultural over-production rather than of reclaiming undernourished soils.

To be acceptable for municipal use, composting should be: 1) Universally applicable; 2) Dependable; 3) Competitive economically with other accepted methods; 4) Nuisance-free; 5) Centrally located to tributary collection

106. areas; 6) Rapid; 7) Independent of weather and climate; 8) Not requiring marketing by the municipality. Present promotional activities lack dependable experience and generally overlook many of these basic items. Mr. Rogus concludes:

"1. Further extensive research on composting of municipal refuse should be encouraged as part of a long range program for the conservation of natural resources.

"2. Such research, including development studies through construction of a full scale composting plant, should be subsidized by and should be the responsibility of a federal agency.

"3. An acceptable plant for composting municipal refuse should be competitive with other modern disposal methods both as to costs and as to nuisance-free operations - all without tie-ins to unproven and undependable benefits of the salvage and sale of by-products."

107. Snell, John R. Composting of municipal refuse. Canadian Inst. on Sewage & Sanitation (Presented at Toronto), mimeo. 11 pp, Oct. 28, 1957

The next step in development of composting of municipal refuse is to construct a scientifically designed full scale plant somewhere in the U. S. or Canada. Author mentions 8 processes in limited use today in the U. S. He names three other processes which are recommended as "most fully employing the scientific principles learned to date, and still combining economy and efficiency." a) T. A. Crane high-rate digester (30 ton/day plant built in late 1956 by Kobe, Japan); b) Amer. Dross Disposal Corp. automatic turner and shredder used in conjunction with "forced-air windrowing" (see 43); c) Bin composting with forced-air as employed in a second stage to high-rate composting in the Kobe, Japan plant. Some of the work at Michigan State University (which see) was described. Results of operation of the Crane type plant (48-hr. retention) followed by bin composter (curing, with forced air, for 7 days) were reported as:

	% H_2O	% Ash	% Vol. solids	%N	C/N
Raw material	62.7	44.2	55.8	0.78	39.8
Material on bottom deck	54.3	53.9	46.1	1.08	23.7
Finished Compost	51.5	58.3	41.7	0.97	23.3

107. True market value for compost in any area will have to be shown by time but to the farmer it is worth about $20-25 per dry ton as a fertilizer and as organic matter. The author then proposes a prototype plant: a) At almost any city in U. S. or Canada with 100,000 or more population; b) Plant centrally located within the city to the collection trucks, or at the sewerage plant; c) Plant to treat refuse with or without sewage sludge; d) Incorporate salvage operations; e) Pre-grind the materials; f) Composting by each of 3 methods given above /the author specifically recommends omission of these types: ORCOA (as at McKeesport, Pa.); Sanitary Disposal Corp. (as at Williamston, Michigan) Earp-Thomas (as at Seoul, Korea); Frazer process (as at Bay Shore, Long Island); and ordinary windrowing (without forced air)./; g) A 3-in-1 installation similar to that at Kobe is recommended. The author deplores the conservativeness of cities in adopting new methods and suggests possible means of financing. Estimated cost is $2,000/ton or $200,000 for a 100-ton installation.

108. Snell, John R. Composting your organic wastes at a profit. Pub. Wks. 88(11):108-10, Nov. 1957

Moderate to large size composting plants can be a financial success, under most conditions. Composting also conserves waste for a useful purpose. Most U. S. cities spend $1-5/ton to dispose of refuse. Profit with composting should be $2-5/ton of raw material. Composting will also aid in disposal of sewage solids along with combined refuse. Sewage sludge improves composting, giving a better end product and less over-all costs. These organic wastes amount to 10 million tons/year in U. S. cities and are estimated to be worth over $350 million/year. Similar economic benefits can accrue to certain industry plants. Examples are: canneries, meat packers, paper mills, saw mills, tanneries. Modern composting is a fast, efficient aerobic process. Stabilization is accomplished by microorganisms which use large volumes of O_2 and produce temperatures of 160-170° F. Conditions for good composting: 1) Raw material C/N of 50 or less, no serious food deficiency, and pH 5.5 to 8.0; 2) Material finely ground; 3) Moisture controlled at 50-60%; 4) Recycle seed compost in ratio of 1/10; 5) Aeration with at least 50% O_2 throughout.

For high-rate composting, add: 1) Constant slow stirring or intermittent stirring every 5-10 minutes; 2) Control of temperature; 3) Prevent excessively high pH to avoid

108. N loss; 4) Continuous flow in 3-4 stages, thorough mixing for each stage. Last stage may combine slower digestion with natural drying from the produced heat.

Composting takes 10-15 days without a mechanical unit, 1-3 days with. Major objectives are: 1) Stabilize putrescible organic matter; 2) Kill pathogens; 3) Conserve N; 4) Produce uniform ground end product, free from glass; 5) Compost so as to be free from flies and odors; 6) Operate in inexpensive, uninterrupted, and foolproof manner. More research is needed on N conservation. Author believes all objectives except complete conservation of N can be achieved with present knowledge. He recommends 3 approaches as being efficient and economical: Mechanical digestion, modified windrows, and bin composting. Six mechanical digesters are on the market but 3 use essentially a batch process. The 3 continuous flow models are: 1) Dano digester composts 5 days in a slowly rotating horizontal cylinder. Dano plant is operating in California; 2) Earp-Thomas digester is an 8-deck vertical cylinder with plows for mixing and aeration. A. O. Smith Co. has re-designed unit to improve mechanical features; 3) T. A. Crane digester is a 3-deck horizontal unit with agitating and aerating mechanism for each level. The first Crane unit was a 30-ton/day plant in Kobe, Japan. Modified windrows - using forced air with periodic turning and shredding - are much more efficient and require less time than ordinary windrows. Windrows should be 4-6 ft. high x 8-12 ft. wide. Under each windrow is an aeration pipe. A special machine picks up, shreds and lays down all the material several times during the process. A less efficient system is with a front-end loader and a large shredder. An initial installation is scheduled for Fall of 1957 at Omaha stockyards. Authors cost estimate for stockyard wastes composting is $1/ton of raw manure or $2.50/ton of dry compost.

Composting bins 4-8 ft. deep with forced air from floor was first developed at Michigan State University. A full-scale plant has been completed in Kobe, Japan. Materials handling is a big problem in composting design, but further errors should be eliminated. The science of economical composting is much more complicated - should not be treated lightly. Estimated theoretical value of compost is 20-30/T on a dry basis, but sale at $5.00/T should bring a small profit to a city of 100,000 plus. There are unlimited markets to farmers at $10/T and to city users at $60-80/T in 50-lb. sacks ("very substan-

108. tial markets"). Recommends that cities sell the compost in bulk to commercial companies already in the fertilizer business. "Marketing of organic wastes will take care of itself as soon as substantial volumes are composted and available."

109. Stoller, B. B., Smith, F. B., and Brown, P. E. A mechanical apparatus for the rapid, high-temperature micobial decomposition of fibrous, cellulosic materials in the preparation of composts for mushroom cultures. J. Am. Soc. Agron. 29:717-23, 1937

Composts for mushroom culture from horse manure are presently made in heaps 3-6 ft. high, turned every 5-10 days with pitchfork, water added to maintain 60-70% moisture. Time required is 4-7 weeks, a longer time is needed with fresh manure with a high amount of straw. Loss in dry weight is 25-40%. Lambert and Davis found more than half of the heap was anaerobic with 20-30% CO_2 and no O_2. Authors tried a mechanical apparatus to get faster, aerobic decomposition at high temperatures. Used a butter churn (approximately 3 ft. diameter x 3 ft. long) with rollers removed but leaving the two baffles which project 3 in. from sides. Installed a 1 in. pipe with 1/8 in. holes 2 in. apart in the center for sampling gases and for blowing air and adding water. The churn was geared down to one revolution per 8 min. Ran O_2, CO_2, moisture and ash. Took O_2 and CO_2 samples one minute after air was turned off. In 24 hours the temperature reached 58° C. with a room temperature of 26-31° C. Highest CO_2 occurred after 16 hours being 12.4%. Air was supplied at 5 cfm. Used about 55 Kg raw material. At 7 days temperature decreased to room temperature. Moisture increased unless it could escape with exhausted air, usually the case in these experiments. Tests without rotating the churn gave non-uniform decomposition with manure near the pipe having a heavy growth of "firefang." The highest temperature and CO_2 were in this layer. Surrounding this was a layer of yellow strawy material (25% H_2O) which showed little decomposition. The outside layer was brown manure (60-80% H_2O) and had little or no "firefang." Free moisture collected in the bottom. In the rotating drum the time required was 7-10 days, there was no "firefang." There was a loss of 20-30% dry matter in 7 days. Ash increased as organic matter decreased. At maximum temperature the CO_2 would reach 19% in 15 min. after stopping air. At 7 days the CO_2 reached 19% in 4½ hours.

110. Stoller, B. B. (L. F. Lambert Research Lab., Coatesville, Pa.) Preparation of synthetic composts for mushroom culture. Plant Physiology 18:397-414, 1943

Based on average analyses of horse manure compost and mushrooms, the author attempted to develop a synthetic compost containing the significant constituents. Horse manure and its straw bedding has: N - 2.0%; P_2O_5 - 1.0%; K_2O - 27% (dry basis). Mushrooms (Agaricus compestris) have: N - 6.44%; P_2O_5 - 24.25% (of ash) and K_2O - 43.94% (of ash). Ratio in mushrooms of $N:P_2O_5:K_2O$ is 6.4:2.4:4.4 and about the same ratio is satisfactory for preparing synthetic composts. The author made up composts of spent licorice roots and added various sources of N (dried blood, cottonseed meal, urea, chemicals). Materials were composted in piles for 30 days (later this time was thought to be excessive). The effects of added salts (K_2SO_4, KCl, superphosphate and $Ca(OH)_2$) to synthetic composts were also studied as related to mushroom yields. Potash nearly doubled the yields over that to which only N and P_2O_5 were added.

The composting time for licorice roots was best around 8 days in small piles but required 15-20 days in large piles with ventilators. It was difficult to get good mixing, watering and aeration in large piles. Some combinations of chemicals with lignin and tannin did not require any outdoor composting. Suitable compost for mushroom growth must heat up to about 140° F. during the "sweating out process" to attain air temperatures of 125-130° F. for killing pests. pH control to 8.0 - 8.5 and excessive N to liberate NH_3 are needed to control another fungus Coprinus and Pseudobalsamia microspora. The latter, causing truffle disease of mushrooms, is killed by NH_3.

111. Stone, Ralph. The Shaoyang, China, night soil fertilizer reclamation plant. Sew. Wks. Jour. 21:992-1001, Nov. 1949

The plant consists of two settling basins for the separation of urine and feces; six small aerobic composting pits; a large aerobic digestion tank, two anaerobic continuous digestion tanks; two anaerobic fill and draw tanks; a trickling filter for oxidizing 1,500 gpd of urine; two sand and gravel sludge drying beds; a mortar and pestle bone crusher for 1,000 lb. dry bone/day. The plan to manufacture NH_3 from urea was abandoned (two settling basins and the filter were designed for

111. this). Aerobic digestion was tried with 1 part night soil, 2 parts cellulose waste (rice straw or ground and sorted garbage), and 1/2 part bone meal. Attempted to hold the C:N ratio above 20 and pH at 7.1 (lime was used). Liquids were recirculated. Temperatures reached 140-150° F. and the time required was 50-60 days. Digested sludge was excavated from the tanks and dried (7 days). The final product (air-dried) had: 3.94% total N; 1.50% P_2O_5; 2.27% K_2O; 42% moisture. Raw night soil was about 96% moisture. Most of the pathogenic organisms were destroyed by heat of digestion. Samples showed 2,000 ascaris eggs/gram of fresh mixed waste and only 100 after one week. These eggs were largely degenerated or dead.

112. Stovroff, R. P.(Compost Corp. of Amer.). Municipal wastes - an untapped natural resource. Ingenieria Sanitaria 7:36-42, Jan. 1954

Present methods of garbage disposal are only refinements of basic methods used for centuries - dumping and incineration. Composting is a method of refuse disposal which also provides a product useful in increasing agricultural yields. Literature is full of opinion but woefully short of facts on composting. The experimental plant of Compost Corp. of Amer. proved that successful operation is essentially a matter of materials handling. Phases: (1) Receiving, (2) Segregation and scrap preparation, (3) Compost preparation, (4) Decomposition or stabilization, (5) Market preparation. Composting garbage with rubbish is more economical than garbage alone. Separation before compost preparation in Oakland was most effective. Composting is done in open air on unimproved land. It takes 3-4 weeks. Time could be reduced but only with the expenditure of additional labor. There is no commercial advantage to this since compost is sold in agricultural markets which are spasmodic and require provision for handling surges in demand. Windrows hold surges of materials needed and will prove satisfactory under most climatic conditions. Freezing is no problem and excessive rain can be coped with by forming windrows, to turn it. "No economic justification for increasing either equipment or operation cost of this particular phase for sanitation standards, climate, or speed of decomposition has yet been found." Composting is a tonnage operation. Oakland figures show 32% return on investment after provision for income tax of 50% of profits. Capital costs (265 T/day) is half that for incinerators.

112. Compost effects on soil: (1) Improve structure; (2) Increase availability of plant foods; (3) Increase effectiveness of chemical fertilizer; (4) Provides source of additional nutrients; (5) Source of minor elements and trace minerals; (6) Increase moisture-holding capacity; (7) Prevent leaching of soil minerals (8) Maintains soil balance; (9) Provides food and housing for soil microbiological life; (10) Helps prevent erosion. Composting is needed and can be done cheaper in Latin America than in U. S.

113. Stovroff, Richard P. Capitalizing on municipal wastes by composting. Amer. Soc. Civil Engr. Proc. Separate No. 545: 9 pp, Nov. 1954

Operation of an experimental windrow composting plant for municipal refuse has been conducted in the City of Oakland, California by the Compost Corp. of America. Although conversion of wastes to valuable compost is biological, it is claimed that profits are contingent upon mechanical efficiency in materials handling. The following basic phases are proposed: (1) Receiving; (2) Segregation and scrap preparation (paper, tin cans, glass, bottles, rags, and metals); (3) Compost preparation; (4) Stabilization or decomposition; (5) Market preparation. Decomposition occurs in windrows in the open on unimproved land in 3-4 weeks. Time could be reduced, but only at unjustified greater labor expense. Windrow composting is claimed to meet all public health standards and all climatic conditions; i.e. freezing and rainy weather.

Cost estimates are presented for the proposed new Oakland operations designed for 265 tons of refuse on an 8-hour day, 5-day week basis. Estimated building and equipment cost is $590,000 with a working capital required of $125,000; total cost $715,000. The plant would produce 125 tons of compost and 80 tons of marketable scrap materials per day. Sales would amount to $1,200,000 (approximately $37/ton) for compost and $255,000 (approximately $12.25/ton) for scrap materials. Thus, with a revenue of $1,455,000, operating costs of $975,000, and Federal income tax of $245,000, the net profit expected is $235,000/year or a return of 32% on the $715,000 investment. Costs per ton of refuse disposed are given as: $1.95 for compost, $0.50 for scrap, and other costs (power, water, maintenance) $0.45 or a total of $2.90/ton of refuse, excluding depreciation,

113. overhead, and other miscellaneous expenses. Compost is reported to be needed to provide organic return to the soil, along with chemical fertilizers. Compost: 1. Improves soil structure; 2. Increases availability of plant nutrients; 3. Increases effectiveness of chemical fertilizer; 4. Provides additional nutrients; 5. Provides minor elements; 6. Increases moisture-holding capacity; 7. Prevents leaching of soil minerals; 8. Maintains soil balance; 9. Provides environment for soil microorganisms; and 10. Helps prevent erosion.

114. Straub, H. The production of compost from sewage and garbage. Proc. Abwassertechnischen Verein I:94, 1949; Abs. Sew. Wks. J. 23:822, June 1951

> "At experimental plant at Baden-Baden fresh sewage solids were thoroughly mixed with garbage, from which larger materials (tin cans, glass, etc.) had been removed. The mixture was stacked in piles 3 x 3 x 100 m. provided with longitudinal air supply shafts and vertical air outlet shafts about 18 m. apart. To obtain best compost (35-40% moisture) fresh (sewage) solids of 75% moisture are mixed with the garbage in a ratio of 1:4 by weight, respectively. Decomposition requires 5-6 months, during which piles should be turned over. The composting produces no odors; H_2S odors indicate air deficiency. To maintain a uniform product, the additional ashes in garbage during winter should be stored and added to summer garbage. Final product is sifted to 25 mm size, leaving a 15% residue, which can be ground and added as seed to raw garbage. Fertilizer value of compost is shown to be equal or better than manure, and better than artificial dry fertilizer, especially for peas, potatoes, carrots, cabbage, etc. Besides the minerals, it provides much needed humus and minute quantities of the trace elements necessary for the health of plant, animal, and man. A balance sheet shows that the product can be marketed more cheaply than any other fertilizer."

115. Straub, Hans. The sewage clarification and compost works of the city of Baden-Baden. Gasu. Wasserfach 92, 24:323-32, 1951; Chem. Abs. 46:2721e

> "Sludge is treated in two-stage digestion tanks with elutriation in between. The washed sludge from the final digestion tank is dried on beds and then mixed with screened garbage from which metals, etc. have been removed. The mixed compost rots for 5-6 months and is screened in a special mill which removes glass, cinders,

115. etc. The compost is sold for slightly more than the cost of operating the compost plant, considerably reducing the cost of garbage disposal."

City of Tacoma. The composting of municipal garbage and sewage sludge - final report and recommendations. (See 102)

116. Taiwan Inst. of Environmental Sanitation (China). Sanitary disposal and utilization of municipal refuse and night soil. 1956 Annual Rept., Part 4, Eng. Summary:11-17, Jan. 1957

A. A survey of 22 cities and towns revealed: 1) Inadequate house storage of refuse; 2) Many leaky nightsoil pits and septic tanks; 3) Increased fly and rat nuisances; 4) About a half million tons each of nightsoil and refuse/year collected by the San. Corps of Police; suburban areas are disregarded; costs are high due to worn-out, inadequate equipment; 5) Refuse disposal: open dump - 66%, anaerobic composting - 24%, incineration - 10%; nightsoil disposal: dumping - 53%, remainder for fertilization without proper treatment; 6) No adequate regulations. Recommendations are made to improve collection and disposal, including the use of aerobic composting, pasteurization of nightsoil used as fertilizer, use of digestion plants for nightsoil where fertilizer demand is low.

B. The Ping-tung Municipal Refuse Composting Experimental Station is the pilot plant for composting in Taiwan, constructed July-Dec. 1956. The plant capacity is 27 tons of raw refuse per day; it treats 20 tons/day. The initial cost was $15,000 (U. S.), including $4,100 construction, $6,800 machinery, and $3,300 laboratory. Components are: 1) Hopper and conveyor for feeding and sorting; 2) Hammer mill; 3) Shredder for turning and aerating. Present operation is windrow composting with periodic turning and addition of nightsoil. Plans are to include use of forced air composting in aeration bins. Cost of composting (20 days) is about $0.95/ton, not including interest on capital. Temperatures rise to 70° C. in 36 hours and remain there for 24 hours. There are no fly or odor nuisances.

C. Sampling and analyses were made on nightsoil under summer conditions. Per capita production averaged 0.83 liters/day with no difference by various income groups. Analyses were: pH - 7.6 to 7.8; total solids - 2.5 to 3.0%; volatile solids - 1.5 to 1.9% (wet basis); chlo-

116. rides - 4,500 ppm; P_2O_5 - 1,250 ppm; COD - 2,700 to 4,300 ppm; K_2O - 200 ppm; BOD - 8,000 to 14,000 ppm. So-called "maturation" tanks reduce volatile solids 50% in 90 days, nitrogen 17%; BOD 90%. Ascaris eggs are common in nightsoil, being highest from poor residential areas. Viability in fresh nightsoil is 57 to 81% which decreases on storage 70% in one month, 40% in 2 months, and 10% in 3 months.

117. Tech. Committee on Natural Resources, England. Sludge and refuse composting generally uneconomic. The Surveyor, July 17, 1954; Abs. Pub. Wks. p 144, Oct. 1954

Composting of household refuse and liquid sewage sludge by local authorities is said to be generally uneconomical. Fertilizing value of screened dust is low and cost of transport and application make its use uneconomical. Nitrogen may be recovered in sewage works cheaper than manufactured by conventional methods. Fertility of the land is not declining as evidenced by increasing crop yields in past 50 years.

118. Thompson, A. T., Jr. A new solution to an old cotton gin nuisance. The Cotton Gin and Oil Mill Press 53:19-20, Feb. 2, 1952

Cotton gin wastes (lint, burrs, stems and dirt) may be economically composted and converted to salable fertilizer. Cost of composting is $1/ton of waste. Time required is 21 days. Wastes from one gin were composted in Rio Grande Valley for the 1951 season. Compost pits 5 ft. deep and 25 ft. wide, as long as necessary, are dug. Material is piled in pits and inoculated with bacterial culture. Moisture content is brought up to 50%. No turning is required and no chemicals are added. Temperatures reached in the decay process are 140-165° F. and experiments indicate that insect breeding is prevented, objectionable seeds destroyed, and pink boll worm destroyed. Further experiments are being conducted at St. Edwards University, Austin, and Texas Tech. College, Lubbock. Entomological control is checked by U. S. D. A. State Health Dept. observations indicate that the neutral colloidal humus produced (comparable to leaf mold or well-rotted manure) shows considerable increase in yields, with or without supplementary chemical fertilizers. Tonnage/year of gin wastes in Texas was estimated at 2½ millions in 1951.

119. Tripp, E. H. The value of treated town's refuse as an organic manure. Chemistry and Industry 58:1102, 1939; Abs. Sew. Wks. Jour. 12:650, May, 1940

The experiments in this article were undertaken by the Rothamsted Experimental Station, England, to investigate the fertilizing value of the manure that is being prepared from refuse of Royal Borough of Kensington. Refuse is dumped into pits. It is picked up by a grab and transferred to the top of towers, whence it passes to belt conveyors. Unwanted materials such as glass, paper, metal, rags, etc. are picked out by hand. It is pulverized in large rotating cylindrical crushers, screened, sprayed with bacterial culture solution, and conveyed to large cells, 180-ton capacity, where for 16 days it undergoes anaerobic and aerobic fermentation. Temperatures rise to 170-175° F., gases are removed through flues and there is no objectionable odor. The plant is designed to treat 250 tons of refuse/day and yield about 160 tons of manure, "Hyganic." Dry matter in the manure was 63.9 - 74.4% (average 70) and N was 0.97 - 1.42% (average 1.16). "Hyganic" was tested in different soils for growth of kale and sugar beets, potatoes and mangolds and compared with $(NH_4)_2SO_4$ and farmyard manure. The organic manures were added on the basis of equal weights of N per acre (0.8 and 1.6 cwt. N/acre and $(NH_4)_2SO_4$ on basis of 0.4 and 0.8 cwt. N/acre. Hyganic gave higher yields of kale and beets than farmyard manure. On equal N basis Hyganic was superior to farmyard manure 3/4 of time to a statistically significant extent. Hyganic sold for 9 shillings/ton.

120. Truman, H. A. Disposal of wastes - composting. New Zealand Institution of Engineers - Proc. 35:443, 1948-9

Small scale composting was started at Dannevirke in 1944 and larger scale in 1946 by Truman. In 1944 the plant had four bins 6 ft. x 6 ft. x 4 ft. high with iron grid bottom and under-ventilation; two sides were removable boards and the back and two ends of concrete. Garbage, garden refuse and abattoir wastes were placed in layers well mixed with alternate layers of 4 in. of soil. Percolation of liquid resulted from abattoir wastes which caused odors and also fly breeding was created due to low temperatures and inadequate aeration (maximum temperature was about 100° F.). Composting was for about six months and the resulting humus was good.

In a second experiment all types of garbage and refuse were used plus septic tank sludge and effluent. Sawdust

120. (33%) was used as cover to absorb rain and assist in aeration and physical quality. Materials were separated (bottles, metals, etc.) with refuse deposited in bins, covered and impregnated with sludge, turned, and final humus pulverized and screened for stockpiling and maturing. Bins are 30 ft. x 10 ft. with 2 ft. 6 in. sod walls. Bins have 4 in. or 6 in tiles on 2 ft. 6 in. centers on the earth floor. Material is layered in 4 in. layers and dusted with $CaCO_3$ and superphosphate, then covered with a layer of sawdust or shavings and moistened with sludge. Dense packing is avoided. Piles are 5 ft. 6 in. high rounded off to shed rain. Temperature reaches 150° F. quickly and rises to 160-170 (peak was 184° F.). Temperature is maintained usually about 2 months, and gradually drops to 100-120° F. Compost is then turned and the temperature again rises to 150-160, repeating the cycle. Heaps are turned three times and stockpiled. Factors are moisture (50-60%), aeration, non-acidity, temperature and bacterial food. Turning is done by a clamshell. Total compost time is 6 months. The population is 4,800, rainfall 48 in., average winter temperature 40° F., refuse (loosely packed) weight 70 lb./cu. yd.; sewage flow 300,000 gpd, refuse 180 tons/year, trade waste 50 tons/year.

There is a 50% weight loss on composting. The compost sells for 5 pounds/ton. The method of determining the state of maturity of compost is considered. Chemists use C:N ratio. Some suggest it should be about 10:1. Stoughton says 20:1 is the critical ratio for household refuse and that composting pulverized refuse leads to a final lowering of the ratio to 12:1. Reduction to this point in compost is considered wasteful by Stoughton since much dry matter is lost. Bould states that compost will not immobilize N in soil if it meets one or more of the following: (1)'Corrected' C/N is less than 20; (2) N expressed in terms of loss on ignition is greater than 3.0% (usually it is stabilized at around 3.5%); (3) when mixed with soil and kept at optimum moisture and temperature conditions NO_3 are liberated (nitrification test); (4) When mixed with equal dry weight cellulose and given optimum conditions of moisture, aeration and mineral supply other than N, increased evolution of CO_2 occurs (fermentation test). Truman tests composts in seed boxes and also runs chemical tests. In one case he got good pot results with a C:N of 45:1.

120. On pathogens the Union of S. Africa, Department of Public Health states:"There is no likelihood of matured compost, used as a fertilizer, acting as a medium for the dissemination of infective material of amoebic dysentery and parasitic worms, provided the process of composting has been carried out in accordance with instructions issued by the Department of Agriculture and Forestry, where temperatures of 150-160° F. are attained in the pits for 2-3 weeks." J.P.J. Van Vuren stated that cysts of amebic dysentery are destroyed at 123° F. for 2 minutes.

Weaknesses in compost process are: Pulverization is needed; it could be done by a masticator of the "Lightning" type. Mechanization of screening and handling is also needed. Composting beds should be provided with shed roofs.

App. A - G. Bransby Williams - Notes on principles of Composting. App. B - F. H. Ransome - Straw-sludge manure. App. C - Dannevirke Council - Household Refuse Collection. (See also 79.)

121. Upholt, W. M. Resume:Symposium on Composting at Western Branch APHA Meeting, May 11, 1954, Seattle. Unpublished report, May 14, 1954

(1) Dr. Clarence G. Golueke, Biologist, University of California, indicated that the same temperature curves and time of composting occurred whether inoculins were used or not. On the end point of composting, the C:N should be 20:1 or up to 25:1 with slowly decomposing C such as newspaper. Above 20:1 plants may be stunted, below 20:1 there is loss of N. The end point is usually satisfactory after the temperature drops to 120° F.

(2) C. S. Seabrook, Sanitary Engineer, Tacoma Sewer Department - Composting has been conducted for a year at the City of Tacoma. No grinding or segregation is provided. Composting in windrows on gravel, turned twice weekly with a bulldozer. The time required is about 6 weeks. In the rainy season the composting was satisfactory but in drier seasons it was necessary to add water to keep moisture up to 40-60%. The final product screened readily through 1/4 in. screen and trash or non-compostable material was quite clean. The cost of production is $2.50/yard, selling for $3-5/yard. It is computed that 1/8 of the total garbage must be

121. salvaged or buried.

(3) Cecil J. Geraghty, Construction Engineer, Clyde C. Kennedy Engineers, San Francisco, believes composting can be done efficiently without segregation or inoculin, recovering two-thirds of the material as humus (1 ton yields 1 cu. yd. of humus). Composting will not eliminate the sanitary fill. Composting will treble the cost of fill, adds \$1.50-\$2.00/cu. yd. Finished humus should analyze 1½-1-1 (N-P-K) which should bring \$5.50 per ton. One ton of humus equals about 1½ cu. yds. Composting gives greater cash return than hog feeding.

(4) Prof. Gilbert A. Dunstan, Dept. CE, Washington State College, Pullman, emphasized the need for research on the value of organic farming and compost.

(5) Prof. Richard Tyler, CE Dept., University of Washington, Seattle - Non-segregated waste is less compact and has better aeration. The University conducted some tests on the use of activated and digested sludges as supplements to garbage composting. Some speeding up occurred by the addition of activated sludge, though there was a tendency for it to collect on the ground beneath.

It is believed there is a definite advantage in combining sewage disposal with garbage composting. A possibility of using snow plows instead of bulldozers in turning heaps was suggested as bulldozers tend to compact the materials too much.

122. V.A.M. Refuse Disposal Company (N.V. Vuilafvoer Maatschappij). The processing of city refuse into compost in the Netherlands. Pamphlet, 20 pp, 1955

It is claimed that both organic manures and chemical fertilizers are needed in the soil. Disadvantages of sole use of chemical fertilizers are: wind erosion, decreasing output, increasing deficiency diseases of plants, increasing sensitivity to drought, cultivation difficulty in heavy soils, increased susceptibility to parasitic and infectious diseases, smaller crop certainty and more dependence on favorable weather conditions. Composted refuse has more value than farm manure because it contains coal ashes rich in trace elements and it provides small particles which increase base-absorbing and water-holding capacity of soil. The

122. Wijster compost has 4.5 to 12% real organic matter (excluding unburnt coal) and 0.4-0.5% N, 0.4-0.5% P_2O_5 (acid soluble), 0.2% K_2O (water soluble), 3.0% CaO (acid soluble), 0.3% MgO, 25-30% water, 18 to 25% volatile solids, 0.04% Cu, 0.04% Mn, 0.03% Zn, 0.002-0.005% B, 0.003% Mo, and 0.003% Co. Schiedam compost is somewhat higher in organic matter during the summer.

V.A.M. was founded in 1929 and has built the largest compost plant in the world at Wijster, serving the Hague. Groningen (since 1950), and Zandvoort (since 1951). Two smaller plants were built in 1951 at Flushing and Schiedam using another method. The process at Wijster is the "Van Maahen" process. It avoids manual labor, keeps costs low by handling large amounts of refuse, and is self-supporting. Refuse is hauled in 130-cu. yd. (33-ton) closed railway cars with saddle-shaped bottoms sloping 45° which are automatically unloaded by steam on viaducts (520 yards long, 6.6 yards high) on both sides. Grab cranes level the refuse which is wetted from a sprinkling system using recirculation. Temperatures rise to 70° C. and then reduce to 50° C. in a few months. Compost is turned by special grab-crane after 3-4 months in winter, 6-8 months in summer. Compost is loaded into a rolling spraddle hopper by a 3-ton movable bridge crane with a grab. Saddle-bottom lorries, attached to an endless steel cable are charged from the spraddle hopper above and are discharged automatically into bunkers. Vibrating screens are fed by the bunkers by means of drag conveyors. Screened compost (passing 3/4-inch) is conveyed to a barge or lorry, then to the purchaser. The next size (passing 2 3/4-in. mesh) is conveyed past a magnet to a hammermill which grinds and then throws the material against an iron plate so that hard particles (cinders and coke) are separated by rebound. A second screen (5/8-in. mesh) is then used on ground material with tailings removed. A final coarse screen (6-in. spacing) separates out larger materials, the screenings passing a magnet and hand sorting belt for removal of non-ferrous metals. Tailings, amounting to about 20% fall into lorries going to the offal dump. The loss in weight during composting is 5-10% and annual compost output is 105,000 tons. Iron is baled and sold; it amounts to 1.4%. Non-ferrous metal, 0.033% is also sold. Offal is covered with fine sand or other material and "let out" to farmers nearby (used in place as land). The staff is 57 with only 7 in the factory building (screening, sorting, grinding, etc.). Compost sells for 3.25 glds ($0.86)/ton at plant. Demand

122. exceeds supply and there are a great number of regular customers.

Schiedam uses the rasping process. Refuse goes to a bunker (long hopper) with drag conveyor at bottom and is discharged to an elevating conveyor through an adjustable choke plate. Iron, about 2.0%, is removed by magnet, the refuse going to the rasping machine. This is an 18-ft. diameter bowl with floor alternating pie-shaped plates, one having 3/4-inch holes, the next solid but with small steel projections. Rubbing arms sweep over the bottom plates, rasping the refuse which passes through the holes where it is swept off with wings from a solid plate below. Rasped refuse is passed through a roll-crusher to pulverize the glass and cinders still finer. Next a hammermill is used which flings dense material farther than the organics and thus separates glass, cinders and metals from that to be composted. The ground refuse is windrowed, water having been added at the rasp. Compost is turned at 3 to 4 weeks, total time is 6 to 8 weeks. Temperatures are 45 to 65° C. Offal, removed from a slide valve in the rasping machine, constitutes 10 to 15% of total fresh refuse weight. Although the finished product will heat up and is more expensive to produce than V.A.M. compost, the composting requires less time and has a better appearance. It sells for 10 glds ($2.63) per ton, principally to market gardeners.

123. Valdivieso, J. Alfonso. Santa Ana Organic fertilizer factory (Summary). Ingenieria Sanitaria 7:51, Jan. 1954

In 1945 a local private concern established a fertilizer factory in Santa Ana, El Salvador, (52,000 population) using refuse, garbage and stable manure for its raw material. About 10 million Kg. of refuse is collected yearly. The plant cost $50,000. It has an office with truck scales, 6 long open sheds housing 70 composting cells 10 m x 3 m x 90 cm deep, storage for finished product, and a 24 cu. m. tank for raw sewage. Raw material is selected and ground in a hammer mill. One cu. m. of garbage weighs 477 Kg. The volume is reduced 50-60% in composting. A thousand Kg. of organic fertilizer selling at $13 contains: 13.5 Kg N, 29 Kg phosphoric acid, 27 Kg. potash, 640 Kg. organic material, and 290.5 Kg. other materials. The demand is great. Temperatures rise to 50-70° C. and decomposition is supposedly aerobic. There is an ample supply of manure. Coffee plantations use the compost. The compost is

123. turned in 10, 20, 30 and 40 days and requires about 2 months, apparently being moved from shed 1 to shed 6. Raw materials in 1,000 Kg. are:

2 Kg	iron separated
37 Kg	other non-compostable wastes separated.
2 Kg	other residue removed after processing
494 Kg	loss in weight during composting
465 Kg	organic compost
1000 Kg	

Sufficient raw sewage is used to saturate the mass. About 14% stable manure is used.

124. Van den Hande, A. (Ghent, Belg). Some experimental preparations of artificial manure effected in Belgium. Chemie and Industrie 71:85-90, 1954; Chem. Abs. 48:5413e, May 10, 1954

"Artificial manure is prepared by treating straw and composting (7-174 days). Water, liquid manure, $CaCN_2$, and varying treatments of the straw are compared. Organic matter, crude cellulose, C, N, and pentosan content as well as C/N characterize the results. Liquid manure and $CaCN_2$ produce the highest N material, as well as the least organic matter. Treatments lower pentosan and crude cellulose contents."

125. Van der Marel, H. W. Composition of town compost. Chem. Weekblad 46:177-82, 1950; Chem. Abs. 44:5505g

"Street and household refuse of the Hague is composted in heaps 6 m. high and kept moist; the ensuing fermentation raises the temperature to about 70°. After 6 months the product is crushed in hammer mills and applied at the rate of 50 T/ha. as a soil amendment. Annual production is about 100,000 tons. Fifty tons contain: CaO - 850 Kg, MgO - 170, P_2O_5 - 150, K_2O - 260, and N - 100. SiO_2 is 55%; organic matter, including humus, cellulose and coal, is about 23%. Most inorganic plant nutrients are in particles smaller than 3,400 mu. The product has a low fertilizing value but increases the moisture-holding capacity of the soil."

126. Van Vuren, J.P.J. The Manufacture of Compost from municipal waste. Bulletin of Hygiene 18:574, July, 1943; Public Health. Johannesburg, spec. issue 17, 19, 21-24, Jan. 1943

The author is in charge of the municipal compost plant at Ficksburg. The municipal waste includes night soil. Composting is done in pits 12-30 ft. long, 8 ft. wide

126. and 2 ft. deep. Bottoms are drained through perforated concrete slabs to channels sloping to a sump. In order of importance raw materials are: stable manure, straw or grass, weeds, fruit and vegetable peelings, flowers, feathers, paper, sawdust, wood shavings, wood, wool, rags, and other organic materials. Night soil is placed on top of sawdust above a layer of coarse material and animal waste. In 5 days the temperature reaches 130° F. and the material is turned. Temperature then reaches 150° F. The material is turned at 10 and at 15 to 20 days. Fly baiting with sodium arsenite (2 oz.), sugar (3 lb.) and water (4 gal.) is required. After 3 weeks (maximum 4 weeks) the material is turned and piled for ripening. Seepage from drainage sumps may be sprayed over ripening compost.

127. Vick, E. H. Experimental work at the Northern Outfall Works of the London County Council, 1940-46. Part II. *Metr. and Sou. Branch, Inst. Sew. Purif*. 10 pp (presented Nov. 15, 1946; Abs. *Sew. Wks. J*. 19, 1088-9, Nov. 1947

Pulverized refuse (1 part) and primary sludge (1.22 parts) mixed in a concrete mixer failed to ferment satisfactorily under January conditions. Various combinations of sludges and refuse were tested in heaps 7 ft. x 4 ft. x 4 ft. high, some with aeration having two diffuser tiles spaced one foot apart beneath the heap and connected to an air supply at 7 psi. Combinations were: refuse and raw sludge, refuse and activated sludge, refuse only (each with and without aeration), refuse and digested sludge, and refuse and screenings (with no aeration). None of the aerated heaps showed a rise in temperature. The refuse and screenings produced the best results. The rest of the experiments were with 1:1 refuse-screenings (by volume). Alternate layers (1 ft. each) of materials were made and allowed to ferment one week. Then the material was transferred to stacks 10 ft. x 6 ft. high x 100 ft. long and allowed to mature for 3 months. Good results were obtained with screenings-refuse but not with sludge-refuse. Field tests by Department of Agriculture, U. of Bristol on cabbage, beets, mangolds, and potatoes showed both composts to have appreciable manurial value with screenings-refuse somewhat superior. Production costs with an output of 4,000 long tons/year might be expected to be 8 s. per ton. Increases in both quality and weight of crop would be expected. As experiments were with war-time refuse (organic material was salvaged) some improvement might be expected with the relaxation of war-time restrictions.

128. Waksman, S. A.; Cordon, T. C.; and Hulpoi, N. Influence of temperature upon the microbiological population and decomposition processes in composts of stable manure. *Soil Sci.* 47:83-113, 1939

Jars containing mixtures of 10 parts horse manure (fresh droppings), 1 part air-dry cut wheat straw, and 2 parts fresh urine were held at temperatures of 28, 50, 65 and 75° C. for 47 days. Chemical analyses and studies of the organisms were made by the plate method and contact slide method. Plates were incubated at the same temperature as the manure. The two media used were: egg-albumen agar for fungi and actinomycetes, and nutrient agar for bacteria. Slides were placed in contact with manure and removed at various intervals corresponding to the time of plating (2-5 days). Slides were stained with rose bengal for 10-15 minutes over a boiling water bath. Slides were then washed, dried and examined using a 2-mm apochromatic objective (N.A. 1.30) and 12.5 x compensating oculars. Immersion oil was added directly to the preparations.

The material in jars (600 gm. wet weight; 155.4 gm dry weight) was apparently not aerated or stirred. The most rapid decomposition set in at 65° C., followed by 50°, 75° being unfavorable, as only the hemicelluloses were decomposed to any extent. At 28° there was considerable delay (9 days) but later the manure decomposed rapidly. During active decomposition soluble N was rapidly transformed to cell material, accompanying decomposition of CHO. After this proteins were destroyed, liberating mineralized N. NO_3 formation took place only at 28 and 50°. N was conserved in manure only when decomposition set in rapidly (50°). When delayed, due to high or low temperatures, losses of volatile forms of N occurred.

At 75° the animal and fungi population were completely repressed, actinomycetes appeared only seldom and at the surface of the compost. Only certain bacteria, largely spore-forming hemicellulose-decomposing types were present. At 65° the bacteria and actinomycetes were chiefly concerned in the decomposition process. Fungi were rare and no animal forms present. After a time bacteria were reduced and actinomycetes predominated (*Actinomyces* and *Micromonospora*). *Micromonospora* was particularly abundant. At 50° certain thermophilic fungi were very active in addition to the bacteria and actinomycetes. The fungi were of the *Thermomyces* and

128. and Monilia or Oidium groups. They disappeared later. At 28° there were many types: mesophilic bacteria, fungi, protozoa, and nematodes. Bacteria remained predominate. Actinomycetes were almost completely absent.

129. Waksman, S. A.; and Cordon, T. C. (N. J. Agr. Exp. Sta.) Thermophilic decomposition of plant residues in composts by pure and mixed cultures of microorganisms. Soil Sci. 47:217-24, 1939

A mixture of 60% straw - 40% alfalfa (air-dry basis) was used in 30-gm portions incubated for 30 days at 50° C. in Erlenmeyer flasks after bringing moisture up to 75%. Organisms were (1) Actinomyces thermophilus, (2) pure culture of a thermophilic fungus, (3) infusion of fertile manured field soil, and (4) infusion of thermophilic manure compost. On the basis of decrease in dry weight and increase in ash, results were in reverse of the order named above. This points to a definite association of thermophilic organisms responsible for decomposition of plant materials. Three mixtures were then prepared and incubated for 21 and 37 days at 50° C.: 6:4, 7:3 and 8:2 (straw and alfalfa, respectively). In 21 days the best decomposition was in the 6:4 mixture but in 37 days the best was in the 7:3 mixture, judged by loss of dry weight and increase in ash. Mushrooms grew better in 8:2 and 7:3 than in 6:4 mixtures after composting. Additions of minerals $(NH_4)_2SO_4$, K_2HPO_4 and $CaCO_3$, were then made with wheat straw alone. Incubation was at 28°, 50° and 65° C. No growth occurred in 30 days at 65°. Fungus grew little at 28° but well at 50°. Limestone helped. The fungi Thermomyces was used. Further tests showed that fungi at 50° attacked cellulose and hemicellulose vigorously; lignin less. Actinomycetes attacked hemicellulose and to a lesser extent cellulose and lignin. Mixed population from compost gave the best decomposition.

130. Walker, H. H. Carbon dioxide as a factor affecting lag in bacterial growth. Science 76:602-604, Dec. 23, 1932

Bacteria in a fresh, favorable media usually follow a lag phase of growth, a rapid increase in rate of growth (log phase), a period of crisis or stable peak population, and a period of decline. Youth of the mother culture generally decreases the lag period. Lag is affected by the magnitude of inoculating dose, temperature, and composition of both new and old media. The author suggests that lag is explained by the time needed to build up the concentration of CO_2 in the environment

130. or in the cells - to an essential point for growth. Continuous aeration with CO_2- and NH_3-free air increases the lag in test tubes. The author used *Esch. coli* in Dolloff synthetic media at 37° C. with growth determined by plate counts. Aeration was with H_2O-, CO_2- and NH_3-free air in one case and air with CO_2 in another. A third was unaerated. Aeration with air containing atmospheric CO_2 gave more organisms in 12 to 24 hours, unaerated was next and CO_2-free air showed no increase in 24 hours. After aerating the culture for one day without CO_2, the experiment was repeated. In 8-10 hours growth increased rapidly in unaerated and CO_2 aerated tubes, not until 28-30 hours in CO_2-free aeration tubes. The author claims aeration or the sweeping out of metabolic products (except CO_2) does not account for the influence on lag.

131. Wang, Yueh. A field study on the disposal of garbage and night-soil by composting. *Science & Technol. China* 1:80-2, 1948; *Chem. Abs*. 43:3960a, 1949

"Pi-shan, Szechuan, was used for an 8 month experiment in which 18 tons of night-soil was composted with an equal weight of garbage (house waste) producing 20 tons of manure. The compost bricks contained an average of 0.91% N (Kjeldahl), 1.03% P and 22.15% volatile matter (dry basis). The temperature developed (above 60°) was sufficient to destroy disease germs and fly larvae."

132. Warlow, W. P. Disposal of sewage sludge by composting with household refuse: The economic aspect. *Surveyor* 109: 549, Nov. 24, 1950; Abs. *Sew. Wks.* J. 23:1058, Aug. 1951

"The London County Council has conducted experiments on composting sewage sludge and screenings with ground household refuse. Sludge has been barged to sea for 50 years. Disposal of household refuse is a function of the Metropolitan Borough Councils. The County Council was concerned, apart from the desire to return sewage solids to the land, in investigating a method of disposal as an alternate to disposal at sea. It was decided to abandon the production of sludge-refuse compost and to continue the making of screenings-refuse material. The refuse is now of very poor quality organically and it is uncertain whether the continued use of a highly mineralized compost would be satisfactory agriculturally. The location of outfalls is not favorable as regards transportation costs. If the demand for compost should be inadequate, disposal of sludge might be very difficult if the present sludge vessels were not replaced.

133. Westrate, W.A.G. The new Dutch scheme for refuse disposal. The Surveyor CX (3093):369-70, June 16, 1951; Pub. Hlth. Eng. Abs. 31(11):GR5, Nov. 1951

Refuse of the Hague has been treated at the Wyster (also Wijster) plant since 1929; now also from Gronigen and Zandvoort. Plant treats 120,000 tons of compost/year (from 700,000 population), sufficient for an acreage of 30,000. Refuse is transported in enclosed cars by train; wetted with bacilli-bearing water; and fermented 4-6 months. Coarse materials are then ground. Iron is removed by magnets, two men remove non-ferrous metals and bones, most of the work being done mechanically; total of 55 men required. Price of compost 5 s. 6 d. at plant; freight brings cost to about double this to the farmer. Collection is 90¢ per head in addition so that the industry is self-supporting. (V.A.M. shares are government-owned.) An experimental plant at Schiedam (70,000) has a grating machine for chopping raw refuse (efficiency not yet known). A new plant is proposed for Eindhaven (140,000). Flushing (Vlissingen, 21,000) is constructing a plant with a grating machine.

Compost improves physical soil fertility, making available air and water for roots, rich and varied life of bacilli and lower organisms. Compost provides 1/3 stabilized humus and 2/3 unstabilized, on which the bacilli feed. Bacilli make phosphorous and N available. Humus holds water over droughts and also keeps nutrients on the surface (absorption) so that they will not wash away. Coal cinders contain trace elements of Cn, Zn, B, Mo, Mn, Cr which prevent plants from having deficiencies. Compost contains Mg and $CaCO_3$ (see 122 for analysis of VAM compost).

134. Wiley, John S. Earp-Thomas composting plants. Unpublished report, July 1953

This is a report of a trip made to visit G. H. Earp-Thomas at Hampton, N. J., and to Wagner College, Staten Island, to see a small Earp-Thomas process installation. There are no Earp-Thomas plants in the U. S. treating municipal wastes. The plant at Chicago Stockyards was reported to have closed down about a year ago. There is a 6-deck unit at the Earp-Thomas country location which is 6 ft. in diameter and 6 ft. high. It was treating hog manure with a small proportion of garbage and was operating intermittently at the time of visit. Raw material is ground in a Kemp shredder and conveyed

134. to the top of the digester where a "starter", containing special bacteria, is added. Inlet and outlet air piping goes to each deck from two manifolds. Air flow is by natural draft through the outlet stack. Rotating plows on each deck, turned by a central shaft, are driven at one revolution in 4 minutes, 45 seconds. The maximum temperature in the unit was 108° F. in deck #2. The finished compost is fortified with special bacteria and with potash (ashes) and phosphate but not with nitrogen.

The Wagner College plant, located at the Frank Hauber farm, also has 6 tiers. The digester is 6 ft. in diameter and about 9 ft. high. It is operating with cow manure and no bacterial inoculum but with some return tailings. Material is preground in a Kemp shredder and conveyed to the top. The compost has a sharp odor and reheats to 140° F. after composting.

135. Wiley, John S. Frazer-Eweson plant, Bay Shore, Long Island. Unpublished report, July 1953

This is a report of visit to the Bay Shore plant, located at Islip, adjacent to the Bay Shore incinerator. Raw materials treated are: sawdust, paper, manure, tankage, sewage sludge, and grass clippings; no raw garbage or refuse is being treated because of labor cost (sorting). Limestone and rock phosphate are each added at 20 lb./ton but the amounts will vary with raw materials. The plant consists of: picking belt, magnetic pulley, scrap balers, grinder, conveyor, composter, shaker screens, gas burner dryer, bagger. The composter is a 5-cell vertical wooden unit, 14 ft. x 14 ft. x 40 ft. high. Capacity was reported to be 100 tons/week but the plant was only being charged every two days, treating 15 tons/week. The decomposition time is 7 days. The bottom of each cell, except the bottom one, is a pipe grid. Material is dropped from cell to cell by operating two "cutter bars" by hand. A blower supplies air at the bottom and vents are provided in each cell, the top being roofed but with open sides. Difficulties, reported by the operator, are: 1) The final material is odorous and will reheat up to 150° F. unless dried; 2) When raw manure includes turkey and poultry manure, the compost has to be re-dried several times to volatilize off the odorous gases; 3) The grinder (an alfalfa shredder) is unsatisfactory; unhardened blades last only 8 hours; hardened blades last 16 to 18 hours; 4) Because of packing and bridging, it takes two men a full day to drop

135. the composting matter from deck to deck; 5) The bottom cell is emptied by pulling out material with a hoe; 6) The shaker screens are too fine and too hard to keep going; 7) The drier is not as good as desired. Compost is sold for \$56/ton bagged or to dealers at \$50/ton.

136. Wiley, John S. Biocatalysts (1954 Operator's Forum, 27th Ann. Meeting, Fed. of Sew. and Ind. Wstes. Assn.) Sew. Wks. J. 27(5):616-617, May 1955

Limited studies have been made with one so-called bacterial inoculum in the composting of municipal refuse in laboratory units at Savannah, Georgia. Decomposition occurred in 5 to 9 days when the inoculum, mixed with various ingredients (called a "starter"), was added to the refuse. Subsequently, the addition of finished compost was compared to that of the starter and the former was equal to or better than the latter. Use of the inoculum and starter were therefore discontinued. Thermophilic bacteriological counts (50° C.) were made for the following groups of organisms: bacteria, actinomycetes, and fungi. All three groups were present in greater numbers in both raw garbage and finished compost than they were in the inoculum. During the composting process there were generally increases in counts of thermophilic organisms.

137. Wiley, John S. and Pearce, Geo. W. A preliminary study of high-rate composting. Amer. Soc. Civ. Eng. Proc. Paper No. 846:28 pp, Dec. 1955; Kriege, P. H.; Wiley, J. S. and Pearce, G. W. Discussions. ASCE Proc. Paper No. 1048:11-14 Aug. 1956. Both Paper and Discussions were also published as: ASCE Transactions Paper No. 2895:1009-1034, 1957

"Composting combined refuse from Savannah was successfully accomplished in laboratory, batch-type mechanical units in which aeration and stirring were provided. The period required varied from 4 days to 10 days during which time aerobic, thermophilic decomposition took place, producing temperatures of as high as 160° F. Carbon dioxide and water were the two major products given off in the outlet gases and both correlated well logarithmically with the temperature of the compost. Respiratory quotients of from 0.87 to 0.91 were obtained for the oxidation reaction. Duplicate runs made with six (15-gal.) units indicated: a. The rate of stirring the compost was not a critical factor, and stirring rates of from 0.1 rpm to 0.6 rpm or higher were satisfactory with the type of unit used. b. Opti-

137. mum aeration rates, under the conditions tested, varied from 10 to 30 cu. ft. of air per day per lb. of volatile solids. Lower rates resulted in prolonged composting, and higher rates resulted in the rapid cooling and drying of the composting garbage. c. Optimum moisture content of the refuse was from 55% to 69%. Moistures of less than 50% and more than 72% did not permit optimum composting under the test conditions. The compost produced was not completely decomposed. Therefore, additional experiments are needed to determine if this compost is suitable for use as a soil conditioner and humus, as determined by both public health criteria and agricultural criteria."

Mr. Kriege, Pretoria, S. Africa, indicated that greater amounts of protein might have lowered C/N-ratio resulting in higher temperatures but, perhaps, greater loss of NH_3. He uses the toluene distillation method for determining moisture in preference to the authors' 105° C. oven-drying method to avoid loss of volatile matter such as NH_3. Explanation of the initial acidic phase of decomposition was given as due to a fermentation causing fatty acids which later were oxidized by the thermophiles as fast as they were produced. Greater variation in raw materials should have been studied, in relation to optimum criteria for composting, to see if these optima hold good for different types of wastes and different C/N ratios. A continuously indicating CO_2 instrument installed in the outlet gases might simplify air control.

The authors point out that high-rate composting scarcely alters the paper content of the refuse. More experiments are planned in which N is increased (C/N decreased) in a variety of forms but there must be a sizeable C/N range over which composting may be accomplished without appreciable NH_3 loss. It is desired to study municipal refuse first before going to other organic wastes. Less emphasis is placed on C/N than by others in the field.

138. Wiley, John S. Studies of high-rate composting of garbage and refuse. Proc. 10th Industrial Waste Conf., May 9-11, 1955; Purdue Univ. Series 89, Bull. No. 1:306-13, Mar. 1956

Brief description is given of the six 15-gal. vertical laboratory composters used for the study of aerobic thermophilic decomposition of garbage, refuse and other organic-wastes at the USPHS Communicable Disease Center laboratories at Savannah, Georgia. Only air and slow stirring are provided. Various observations and analyses made are briefly described. Relationship

138. of CO_2 production (Y) and temperature (X) of composting was correlated with a line of best fit of: Log Y = 0.01012X-0.4084. Similarly, water produced and evaporated (Y) and temperature (X) resulted in a line of: Log Y = 0.009142X-0.1619 with excellent correlation, also. For the particular refuse and laboratory units, stirring rates of 0.1 to 0.6 rpm and possibly higher proved satisfactory, aeration rates of 10 to 30 cu. ft./day/lb. of volatile solids were optimum, and moisture contents of 55 to 69% were optimum. Composting was stopped in 6 to 9 days and, while decomposition was not complete, the material was brown in color and had only an earthy or moldy odor. Approximately 1/3 of the organic matter is decomposed, mainly to CO_2 and H_2O, and the C/N-ratio was decreased from 34 to 28 with an increase in percent nitrogen and a respiratory quotient of 0.87 (volume of CO_2 produced/volume of O_2 used) in a typical run.

139. Wiley, John S. Progress report on high-rate composting studies. Proc. 11th Indus. Waste Conf., May 15-17, 1956. Purdue Univ. Series 91, Bull. No. 2:334-341, June 1957

Continued studies at CDC in Savannah (see 138) were reported on high-rate composting of refuse. By replacing composting matter in various percentages with raw refuse it was determined that 20 to 25% of raw refuse may be added at one time without interfering with high-rate thermophilic decomposition for more than 24 hours. Presumably a 5-day composting cycle would be feasible. Regarding pH control, it was found that slaked lime in large amount (27% of the initial dry weight) would reduce composting time by one day. Agricultural lime (up to 50% of dry weight) had little effect on pH or compost time. Treatment with acetic acid to pH below 6 resulted in preventing thermophilic action and prolonging decomposition time. Lime treatment did not result in NH_3 losses as reported by others.

Indications are that cooling during the hot phase of composting results in greater decomposition than permitting maximum heat retention. The sampling of outlet gases for moisture determination was improved by using a heated tube from composter to Drierite absorbing tube. Previous results had been low due to condensation before absorption.

139. Preliminary trials using a 110-gal. rotary drum composter gave encouraging results. In the composting experiments these additional chemical analyses were made routine: reducing sugars, lipids (ether soluble matter), and crude fiber. Reducing sugars disappeared by the third day of composting, lipids showed decreases of 43 to 81% by the end of the run, while crude fiber percentages increased during the run but did not change much in total weight. Volatile solids lost during the runs, excluding crude fiber, were from 20 to 60%.

Wiley, John S. Progress Report on High-Rate Composting. Proc. 12th Ind. Wste. Conf. (Purdue Univ.) May 13-15, 1957 (In Press)

See 64

Wiley, John S. Discussion - Pilot plant composting of municipal garbage at San Diego, California. Amer. Soc. Civ. Eng. Proc. Paper 1048:17-20, Aug. 1956

See 2

140. Wiley, John S. Dano composting plant, Sacramento County, California. Unpublished report, Aug. 1957

The author visited the Dano of America, Inc. composting plant in Sacramento County, California. Dr. Ralph E. Scovel is President and Mr. Ben G. Petrucci is General Manager. The plant is 10 or 12 miles east of Sacramento, serving a part of the County and receiving about 12-15 tons of refuse per day. The plant consists of: receiving conveyor, sorting conveyor, paper conveyor and grinder, electro-magnet, loading hopper and conveyor, permanent magnet, bio-stabilizer, final conveyor, and shaker screen. Rags and ferrous metals are salvaged. Sorting removes larger unwanted materials. Paper is ground separately and returned to the main refuse flow which is unground. The bio-stabilizer is a slowly rotating (0.2 or 0.8 rpm) drum with an air blower, manifold, and valves on one side, and a water line and valves on the opposite side. The drum is 10 ft. 6 in. in diameter and 72 ft. long with an additional 4 ft. long outlet housing. There are 24 inlet baffles, designed to push the material forward, and the drum has a slope of 1/2 in./ft. Moisture is adjusted to about 50% and the rotation mixes, aerates, and grinds the refuse. Retention is about 2½ days

140. and plans are to receive more refuse which will reduce the time to 1 day. The shaker screen, with one-inch and five-eighth inch openings, removes primarily broken glass, most of the compost passing through it. The compost is caught in a truck below and dumped in windrows on ground behind the plant building. A laboratory is provided but composting is judged by temperature and physical condition. Temperatures at 4 sampling ports in the drum were reported to average: #1 - 120° F.; #2 - 126°; #3 - 134°; #4 - 140°. At time of visit, which was after a water "spill," temperatures were: #1 - 113° F.; #2 - 114°; #3 - 118°; #4 - 132° (material at ports #3 and #4 was dripping wet). In windrows, the temperatures were: Newly discharged material - 112° F.; 1-day old - 110°; 2-day old - 112°; 7-day old 142°; 14-day old - 130°. Windrows had not been turned or wetted; the older material had dried out to a depth of 2 to 3 feet. It is planned to provide turning and wetting of the windrowed material. This material contained many pieces of glass up to about 1-in. in size. The compost is not being sold at present. Reported plant costs were: total spent $230,000; including $30,000 spent on discarded equipment.

Analyses, made by CDC of samples taken on August 23, 1957 were:

Sampling Location	Raw*	Port #1**	Final**
Composting Time	0 hrs.	9 hrs.	2½ days
Temperature	-	113	112
pH	5.5	4.4	8.5
Moisture, %(WW)	52.9	52.2	49.5
Volatile Solids, % (DW)	84.2	77.3	75.2
Crude Fiber,%(DW)	28.0	25.2	34.5
Lipids (ESM),% (DW)	14.0	8.2	7.8
Nitrogen,% (DW)	1.54	1.31	1.18
Total Sugars,% (DW)	1.6	0.5	0.0
Starch,% (DW)	3.5	9.1	0.5(0.0)
Carbon, % (DW)	40.9	38.1	39.1
C/N	26.6	29.1	33.1

*Pre-sorted (This sample is probably not representative because the raw material was unground).

**Glass and metals down to 1/8 in. picked out.

140. "The above indicates slight decomposition during the 2½-day period. Crude fiber increased as would be expected. Volatile solids decreased some. The lipids decrease indicates poor decomposition. There may be some nitrogen loss but only a slight NH_3 odor was present near the outlet of bio-stabilizer. Sugars seemed to disappear although initial amounts were quite low. Starch indicated good decomposition. The C/N went the wrong way according to above analyses; this may be due to fluctuations in raw material."

141. Wiley, John S. Tillo Products Company, Redwood City, California. Unpublished report, Aug. 1957

"Discussion was held with Mr. Cecil J. Geraghty of Tillo Products, followed by a visit to the Redwood City sewage treatment plant to observe the digested sludge-sawdust composting procedure." Composting procedures consist of: "(1) Spreading a 3- to 6-inch layer of wood waste (sawdust and shavings), peat moss, paunch manure or other material in a sludge drying bed or area surrounded by an earth berm. 2) Discharging about a 6-inch depth of digested sludge on the prepared bed. 3) After permitting the sludge to penetrate and dry sufficiently, operating a tiller or harrow over the bed to mix and aerate the material. 4) Repeating (2) and (3) from one to six or more times. 5) After a sufficient time for mesophilic decomposition (preferably 40 days on the bed), scooping up the material from the bed with a 1-cubic yard or larger carry-all. 6) Stockpiling the material for further curing and for sale." The sludge from five sewage treatment plants in the following seven cities in the Bay area is so treated: Redwood City, S. San Francisco-San Bruno, San Carlos-Belmont, Hayward, and Mountain View.

The end product is marketed for $7.00/cu. yd. as a potting soil or planting mix, under the name, "Tillo," after methyl bromide fumigation to kill weed and vegetable seeds. The raw sludge was reported to contain 2 to 2½% N and the Tillo 1% N of which 50 ppm is available N. Tillo contains, preferably, 35 to 50% moisture and weighs about 1,200 lbs./cu. yd. Equipment consists of a truck and a tractor with blade, tiller, and carry-all attachments. Sawdust was used at Redwood City and the process appeared to have considerable merit with this material. Where paunch manure, raw sludge, or supernatant liquor are used, there may be vector and nuisance hazards. Pathogen survival should be studied (see 100).

142. Wiley, John S. Liquid content of garbage and refuse. Amer. Soc. Civ. Eng. Proc. Paper 1411:8 pp, Oct. 1957

"Moisture is required in aerobic composting for the metabolic activity of microorganisms but moisture content should not be so great as to interfere with proper aeration. The optimum moisture content of mixtures being composted varies with the materials and particularly with the lipids (ether soluble matter) and ash contents of the materials. Determination of the liquid content by the formula:

$$\% \text{ Liquid} = \frac{100\ (\% \text{ Moisture} + \% \text{ Lipids})}{(100 - \% \text{ Ash})}$$

(All values on a wet basis) is proposed as an analysis more applicable to the various types of wastes to be composted than the moisture (water) content. The liquid content formula does not include particle size of the solid materials which has an important bearing on the free liquid present." (Author's summary.)

143. Williams, Raymond A. Verdier process of garbage disposal. Proc. Pub. Wks. Congr. 55:91-4, 194; Pub. Hlth. Eng. Abs. 31(7):GR3, July 1951; Chem. Abs. 45:3104e, 1951

"This French aerobic oxidation process of fermentation, evolving only steam vapor and CO_2, is outlined. It is successfully operated with utilization of mechanical handling and other refinements. Operations at the disposal plant at Cannes, France are described. A plant for 900 tons/day has been designed. The final mixed product of organic and inorganic material is a humic fertilizer and excellent soil reconditioner." - (PHEA Abs.)

144. Williams, Raymond A. Fermentation for garbage disposal. Eng'g. News - Rec. 144(15):36-7, Apr. 13, 1950

A Verdier process composting plant to handle 900 tons of refuse daily is planned for the City of Miami, Florida. The plant is to cost $2,400,000 and will be financed (owned) by the Florida Caribbean Biothermal Operating Co., Inc. Plans are being prepared by Maurice H. Connell and Associates, Miami. The city is to pay $390,000 annually for the disposal service. Miami now spends $1,280,500/year for refuse collection and disposal by incineration. Contract completion date is set for Sept. 1, 1951.

144. The Verdier process is an "aerobic oxidation process of fermentation." Several variations of the Beccari or Verdier (modification of Beccari process) have been introduced and abandoned in the United States - due chiefly to failure in mechanics of handling and processing refuse. The plant will contain: a 48-hour storage bin for raw refuse; longitudinal conveyors to a shredder; transverse conveyors for charging the Verdier cells; reinforced concrete fermentation cells provided with drainage recirculation and air circulation; a mechanical loader and portable conveyor for unloading cells, feeding a conveyor system; shaker screens, separating fine humus from coarse bulk, the fine material going under a chemical feeder to a covered stock pile; magnetic separation of coarse material to remove scrap iron, thence a proportioning separator and crusher; Coarse material, diverted by the separator, may be used for steam or heat by burning. The final mixed organic and inorganic materials will make an excellent soil reconditioner. (Ed. note: The plant did not materialize - see 77.)

145. Wylie, J. C. Composting. The Surveyor (Br.) CX(3093): 373-4, June 16, 1951; Pub. Health Eng. Abs. 31(11):GR5, Nov. 1951

Sewage sludge contains slowly available nitrogen while refuse (British) is high in carbohydrates (CHO) and contains insignificant amounts of N. Because soils need organics of C/N of 12 (20 is harmful), composting mixed refuse-sludge is desired to produce a valuable manure of reduced C/N. Additions of fine dust (ashes) provide minerals and help regulate moisture. Dry CHO may be added to overcome seasonal peaks of highly putrescible wastes. Carbohydrates decompose readily, lignins do not. Composting temperatures over 140° F. result in less N loss than at 100° F. Requirements are: high proportion of CHO, balanced moisture and aeration, proper mixing, adequate drainage, sufficient coarse matter to avoid a solid saturated mass when sludge is added.

The procedure used (in Dumfriesshire, Scotland) consists of layering mixed CHO wastes and dust, applying wet primary sludge, adding ground limestone, mixing the layer, and repeating in 9-in. layers to a depth of 3 ft. 6 in. Moisture drops to 70% in 3 or 4 days when the material is transferred to empty bins or compartments. Temperatures reach 165 to 180° F. 3 to 4

145. days later, falling gradually to 100° F. in about 6 weeks. Then the compost is matured for another 6 weeks on raised floors and under shelter. Resulting compost should have 3 to 3.5% N in the organic matter. If vegetable matter is scarce, up to 120 ton/acre of Russian comfrey may be grown and harvested for composting on waste land. The Dumfriesshire compost, "Eradite" is bagged and sold for 7 pounds, 10 s/ton and 10 s/100 lb. bag.

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